ensure	**ENSURE PROJECT** *Contract n° 212045*

WP4:

Development of a new methodological framework for an Integrated multi-scale Vulnerability assessment

Del. 4.1:

Methodological framework for an Integrated multi-scale vulnerability and resilience assessment

Reference code: ENSURE – Del. 4.1

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Contract Number: 212045

Title of report: Del. 4.1: Methodological framework for an Integrated multi-scale vulnerability and resilience assessment

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Short Description: The deliverable illustrates the methodological framework to assess vulnerability and resilience across different temporal and spatial scales, acknowledging the different domains where the latter may manifest, and in particular in the natural and the built environment, allocating a large importance to the so called "critical infrastructures", in social and economic systems. A set of four matrices has been developed to identify what aspects should be looked at before the impact, that is to say what shows the potential ability or inability to cope with an extreme; at the impact, addressing in particular the capacity (or incapacity) to sustain various types of stresses (in the form of acceleration, pressure, heat…); in the time immediately after the impact, as the ability (or inability) to suffer losses and still continue functioning; and in the longer term of recovery, as the capacity to find a new state of equilibrium in which the fragilities manifested during and after the impact are addressed.

Developing the framework, a particular attention has been paid to the relationships among systems within the same matrix and among matrices, across spatial and temporal scales. A set of matrices has been developed for different natural hazards, including in particular landslides and floods, trying to include as much as possible what past cases, the international literature and prior experience of involved partners have indicated as relevant parameters and factors to look at. In this regard, the project builds on the state of the art, embedding what has been learned until now in terms of response capacity to a variety of stresses and in the meantime identifying gaps to be addressed by future research.

Authors and co-authors: Scira Menoni; Luis Costa, Adriana Galderisi, Claudio Margottini

Partners owning: POLIMI

Main contribution: Myriam Belvaux, Itzhak Benenson, Efthimios Karymbalis, Giora Kidron, Seda Kundak, Guido Minucci, Dennis Parker, Kalliopi Sapountzaki, Sue Tappsell.

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1 The development of the framework for assessing vulnerability and resilience within the Ensure research path

In this section the basic assumptions that constituted the common ground for the project at its beginning are discussed, so as to make explicit what was the starting point, how vulnerability was addressed in the initial submitted proposal. The path traced in the latter has determined to a certain extent the project development and the aspects that have been focused upon.

Since the proposal, ideas and positions regarding vulnerability have evolved and new issues have emerged. The general vision on vulnerability has changed according to innovative literature that has been published in the very last years, after long discussions among partners, and the first applications of the methodological framework to the test case study areas.

Changes and advancement with respect to the initial position taken in the proposal deserve to be shortly discussed, for two good reasons.

On the one hand such an introductory part gives a potential reader the opportunity to understand the project logic without necessarily go through all previous rather long deliverables and reports, on the other to clarify to ourselves the process we went through in the last months and the achievements we deem to have reached collectively.

1.1 The project starting point

The table shown in figure 1.1 represents the starting point of the project and was included in the proposal. It enlightens the recognition of the multifaceted, multidimensional, and multidisciplinary character of vulnerability. In the meantime it represents an interpretation of what is available in literature. In a rather instrumental way, some "schools of thought" had been identified (represented in columns) as they offered definitions and assessment methods that were considered significant (summarized in the first large raw). In the lowest part of the table (the second smaller raw) weaknesses or constraints of the approach followed by each "school of thought" or by some of its relevant scholars are briefly reported.

With respect to the scientific and technical domain, the fundamental contribution of the seismic scientific community is acknowledged, while the tendency to overlap the two concepts of vulnerability and damage is depicted as a weak point.

The second column reports some literature quotations taken from the geographical school that has always considered vulnerability as a key concept to differentiate between societies' ability to cope across regions and nations. Vulnerability is clearly linked to sustainability issues, involving qualitative and quantitative aspects of socio-economic development. The major limitation to this kind of otherwise enlightening studies is that they do not provide parameters to measure differences among places (Cutter, 2000).

The third column derives from systems engineering, at the core of industrial risk analysis, where failure and top events are considered as the result of long chains of minor failures, finding their way through latent vulnerable elements in the system. Interesting aspects of this approach relate to the need to consider human and physical elements as strictly interconnected and vulnerability as the result of interaction among various systems and subsystems. Furthermore, the notion of "latent element" introduces the idea of "slow onset" of disasters, any disaster, as mentioned by Lewis (1999, p.161).

Scientific and technical domain	Geographical and sociological domain	Systems Engineering	Ecological field	Climate change studies
Aa.Vv., ***Natural disasters and vulnerability analysis.*** Report of expert group, Rep. Undro, July, 1979. *Petrini V* ***, Overview report on vulnerability assessment*** *in Proc. of the V International Conference on Seismic Zonation, Nice, France, Oct. 1995, vol. III, pp. 1977-1988*	Dow K., ***Exploring differences in our common future(s): the meaning of vulenrability to global environmental change,*** in Geoforum, vol. 23, n.3, 1992 Ramade F., ***Les catastrophes écologiques*** , McGraw Hill, Paris, 1987 K. Hewitt, ***Regions of risk. A geographical introdu-ction to disasters,*** Longman Singapore, 1997	Giarini O., H. Loubergé, ***La delusione tecnologica. I rendimenti decrescenti della tecnologia e la crisi della crescita economica,*** Mondadori, Milano, 1978. Perrow C., ***Normal accidents Living with high risk technologies,*** Basic Books, New York, 1984. V. Bignell e J. Fortune, ***Understanding systems failures,*** Open University Series, Manchester University Press, 1984. J. Fortune e G. Peters, ***Learning from failure. The systems approach,*** John Wiley &Sons, London, 1995	Gunderson L., C. Holling, ***Panarchy. Understanding transformation in human and natural systems*** Island press, 2002 Holling C.***, Resilience and stability of ecological systems,*** Annual Review of Ecology and Systematics, vol. 4., 1973	J. Kasperson, R. Kasperson et al., ***The human dimension of global environmental change,*** MIT University Press, 2003. Turner B. et al., ***A framework for vulnerability analysis in sustainability science,*** PNAS, July 8, vol. 100:14, 2003 Folke C., S. Carpenter, ***Resilience and sustainable development: building adaptive capacity in a world of transformation*** , Env. Advisory Council, Ministry of the Env., Sweden, 2002
** Confusion regarding vulnerability and exposure factors should be avoided* ** Concepts of damage and vulnerability should not overlap*	** The vulnerability factor has to be consi-dered in spatial, regional and social terms* ** Vulnerability with respect to economic developoment and underdevelopment*	** Vulnerability as the result of systems interaction* ** Vulnerability compounds physical, organizational, functional factors as well as managment failures*	** Vulnerability as the result of systems interaction* ** Vulnerability compounds physical, organizational, functional factors as well as managment failures*	** Vulnerability as the result of systems interaction* ** Vulnerability compounds physical, organizational, functional factors as well as managment failures*

Figure 1.1: Table showing the different interpretations of vulnerability considered at the beginning of the project

The fourth column refers to ecological approaches that have recently developed into a more coherent and complete resilience theory, stating that biological and ecological systems have the ability to resist collapse, by enhancing their level of interconnectedness, complexity and diversity. This perspective has entered into risk studies through the scientific groups working on climate change. Turner et al., (2003) state: "Vulnerability rests in a multifaceted coupled system with *connections operating at different spatio-temporal scales* and commonly involving stochastic and non-linear processes".

The last column widens the perspective to the climate change approach, where the notion of vulnerability has evolved significantly in the last years, shading light on fundamental aspects of coping, adaptive capacity of societies and individuals in the face of change. Within the climate change research, the concept of vulnerability blends together the notion of local sensitivity to an "external global stress" and the idea developed within ecological studies that the capacity to resist and adapt to change requires much more than just being able to resist without being damaged. The dynamic adaptation to changes is considered essential not only for ecosystems but also for human systems.

The first need arising from the description of figure 1.1 is in terms of *integration*. A large number of studies and vulnerability assessment proposals have been produced in the last decade in particular, looking at all the facets that are shown in the table. Yet, there is still the need to integrate social vulnerability with other types of vulnerability (economic, cultural, systemic and physical) into a single unified and satisfactory model. What seems to be predominant in the field of vulnerability studies is a net separation between "soft" and "hard" sciences approaches. Here, social vulnerability stands alone, while civil and structural engineers are trying to develop parameters helping judge if and at what conditions a given building or infrastructure would be able to sustain the pressure of an extreme event. Such a separation should be avoided, by considering physical and non-physical aspects as components of the same environment.

The need for integration derives from the principal scope of the project, which is developing a methodology and relative tools to assess the vulnerability of complex natural and built up environments, including rather than excluding the connection with social and economic vulnerabilities. All the dimensions searched by the various disciplines are essential to this main aim, as each provides a piece of the very complex puzzle needed to describe why and how an urban or a regional context responded to an extreme stress, like an earthquake, a flood or a volcanic eruption.

In the historic development of "disaster" studies, such response has been for long attributed to the severity of the stress itself, so that losses and damages were explained with the magnitude of the earthquake, the peak discharge, velocities and height of floods, or the grade on the explosive index for a volcanic eruption. As Weichselgartner and Obersteiner (2002) correctly put it in an article in which they analyzed the past and the future of risk research, a strong need to move from hazard oriented assessments towards more comprehensive approaches putting at the centre the vulnerability and resilience of exposed systems has been generally felt and not only among social scientists, traditionally more attentive to the response capacity of societies and individuals.

Such a strong need is testified not only by the decision to choose vulnerability as one of the leading topics in natural hazards research for the VII FP, but also by its inclusion in even the most technically oriented conferences and in its increasing role in international organisations' documents.

It was clear to the Ensure project since the beginning that the several facets and the articulated interpretations of vulnerability constituted a richness and not a negative aspect: the challenge was therefore how to operationalize such complexity, how to build a method that enables administrations and any other interested stakeholder to carry out a vulnerability assessment providing a comprehensive and the most exhaustive possible picture of elements of strength and weakness in a given environment that could lead to failure or to successful overcoming of "calamities".

In this regard a couple of further preliminary assumptions should be introduced before proceeding in the description of development and results of the Ensure project.

The first refers to the operational character of the tool that has been developed. Being able to operationalize the extremely rich and articulated interpretations of vulnerability was a key motivation for starting the project. A project milestone was the belief that proposed methodologies and scientific advancement in disaster studies should not be considered only per se, but should also serve the fundamental purpose of risk mitigation and losses reduction. In other words a fundamental question that is being asked along the entire project is how a given interpretation, a given tool, can be used for prevention purposes, how it may enhance the capacities of societies to avoid the most dramatic outcomes of natural extremes and to facilitate recovery. This is also the reason why the project attempts to build on previous knowledge, taking advantage of what has been already accomplished in the field, trying to embed as much as possible available results of risk and vulnerability assessment experiences, in the convincement that risk mitigation is inevitably a multidisciplinary, multi-stakeholders endeavour.

Apart from being operational, the tool that we aimed at developing needs also to be "explanatory" in the sense it should help stakeholders understand why given damages occur, how they can be eventually reduced acting on the different components of the risk function, where R = f (H, V, E, ..) (H being the hazard, V the vulnerability, E the exposure).

In this regard, since the beginning it was considered important to separate the expected damage from vulnerability, intended as a propensity to damage, as the compound of characteristics which make a given environment, a given society more prone than another to be severely affected by an "external" stress. On the other end, vulnerability was kept separated from exposure, the latter defining the elements, systems and populations that are located in a hazardous place. Vulnerability implies how "weak" or "strong", how "fragile" or "resistant" is the exposed system, element or population. Both have been included in the evaluation framework, though bearing in mind the just mentioned distinction.

Within previous WPs, and particularly the first, devoted to the state of the art on the issue, the problem of definitions has been extensively tackled. Yet, there is the need to make a choice; the Ensure working group holds that a project, to accomplish successfully its task cannot simply remain at a definitional stage, comparing literature proposals; it must advance its own proposal, selecting, deciding on the interpretation that better fits partners' previous experience, the results of discussions during meetings and the analysis of case studies, both those used for gaining new insight and information and those used as test areas.

Some choices were already implicit in the way the proposal was constructed, other relevant issues emerged during the project development. The latter deserve to be considered before moving ahead to the description of the integrated framework.

1.2 Logic connection between the proposed framework and results of previous WPs

The framework that was finally proposed embeds, in fact, some fundamental theoretical and practical aspects searched in previous work packages, which will be discussed in the next paragraphs.

1.2.1 The need to adopt a systemic approach

The Ensure project adopted systemic approach to vulnerability and resilience assessment. Yet it is important to exactly define what "systemic" actually means. In WP1 and WP2 the various facets of vulnerability (physical, functional, organisational) and the "types" of vulnerability that can be found in literature (social, economic, territorial) have been explored. The framework was conceived as intrinsically systemic, in that various factors, systems and components concur to create vulnerability and resiliency patterns, both individually and through their multiple connections.

More specifically, the framework adopts a systemic approach at three distinct levels:

- first, the vulnerability and resilience of systems is appraised (natural, built environment and social) as it will be further explained in paragraph 2.3;

- second, the term "systemic" has been associated to vulnerabilities that arise as a consequence of systems interdependency and interconnectedness (paragraphs 2.1 and 2.3;

- third, the question of how the vulnerability and resilience of different systems interact with one another across temporal and spatial scale has been addressed (paragraphs 3.2 and 3.3).

1.2.2 Relationship among different vulnerabilities

WP2 can be considered a sort of turning point in the project, as it permitted to extensively analyse and search the relationship between different types of vulnerabilities as described in the previous paragraph: between physical and systemic, between physical, systemic and social, between systemic, social, economic, institutional and territorial. The various types of vulnerabilities are not separated one from another, they actually influence each other. For example physical vulnerability is often the result of lack of good norms and regulations of the construction sector to build more resistant structures but it may be as well the result of poor inspection capabilities, of lack of compliance with existing rules and norms, no matter how well advanced they may be. Furthermore, as it was clearly raised during the development of WP2, the various types of relationships constitute an integral part of what has been labelled as "territorial" vulnerability. Referring to the concept of "territory" in Latin terms serves to make clear that the vulnerability of a region, a metropolitan area or an urban centre is much more than just the sum of the vulnerabilities of individual constructions. It has to do with the way regions, cities and their assets and facilities function, perform and are used by people, agencies and organisations.

1.2.3 Vulnerability in time and space

The fact that vulnerability holds relevant temporal and spatial dimensions is well recognised in literature (while it may be stated that the relationship among different types of vulnerabilities described in WP2, even though well documented, has not been at the core of most investigations on vulnerability until now).

With respect to time, several aspects have been considered. First, it was recognized that vulnerability should be considered as a dynamic rather than static concept: vulnerabilities are shaped over time; vulnerabilities that we are able to assess today are the result of historic processes, shaping cities, communities, infrastructures in a way that builds their potential relationship with hazards. On the other hand, different types of vulnerabilities become more apparent and relevant at different stages of the disastrous event: at the impact, physical vulnerabilities transform into the direct physical damage provoked by the event; during emergency and recovery, systemic, social, institutional, organisational factors determine how slowly or how fast return to normalcy will be possible and at what conditions (for example with respect to the possibility/capability to reduce or increase pre-event vulnerability).

With respect to space, two main considerations constituted the ground for analysis: on the one hand the relevance of space per se, on the other the concept of scale.

As for the spatial dimension per se, we may found in literature since long ago, the distinction between places that are differently affected during the same event: the so called core of the disaster, its "epicentre", where physical damage is more prominent, and the "periphery" of the event, which is directly and/or indirectly involved in the disaster. In fact, different types of long distance effects can be considered: areas from where help will be provided and to where people will be temporarily evacuated in case of need enter into a new type of relationship with the affected areas. New or increased transportation will be required; a flow of goods, services and resources will reinforce and sometime create new linkages. It would be limiting though to consider only the connections arising for emergency and recovery management purposes: remote areas may be affected by the lack of services, by the interruption of major transportation routes or simply because economic relationships exist with the stricken areas and, some firms will be affected by interruption of activities in the impacted zone.

The fact that different areas from those directly affected by an extreme event must be considered, leads to the need to enlarge the overlook from the "local" scale to larger scales, considering how the "local" is placed within larger economic and administrative regions. Some authors have stated that vulnerability assessment is inevitably local; the Ensure project aims at challenging such position by showing that a more complex approach is required, because some vulnerabilities are local, or are particularly relevant locally in shaping the damage (like physical), but others make sense only when larger scales are considered (see for example systemic or social, when the latter include administrative and institutional vulnerabilities). The same consideration regarding scales becomes relevant when the natural environment vulnerability is considered.

Furthermore, some vulnerabilities are actually evident at larger scale because of the nature of the threat and the intrinsic features of systems. The Eyjafjallajökull eruption in Iceland in spring 2010 showed how vulnerable the aviation system is to the consequences of a volcanic explosion provoking ash clouds endangering flights. A rather "local" event, the consequences of which may nevertheless spread over very large zones; an event that has not provoked significant physical damage, losses or victims, but with a very large impact over transportation system and through the ripple effects in economic activities on the entire aviation industry and on the tourist sector.

Finally the scale at which vulnerabilities are relevant depends on the institutional, economic and social arrangements in the different contexts, making clear that a unique rule for deciding a priori at what scales a certain analysis must be conducted does not make particular sense. The selection of relevant scales will depend on the context, and on the particular way in which different systems are connected and related to each other.

1.2.4 Vulnerability and resilience

In the project proposal, vulnerability was the main topic to be searched, with little consideration of other definitions that were considered in WP1 as part of the state of the art. Nevertheless during the project development, a consensus among partners was achieved regarding the need to make explicit the relevance of resilience. For the detailed discussion regarding the differences and overlapping meanings of vulnerability and resilience, it is worth to refer to the deliverables resulting from WP2; what is important here is to make clear how resilience entered in the Ensure project and how it is considered in the proposed integrated framework that will be described in subsequent sections of this report.

The main output of long discussions, readings and reflection is that resilience cannot be simply considered as the "flip-side" of vulnerability. In other terms, a resilient community is not just a community manifesting low levels of vulnerability. A community may be even vulnerable, particularly as far as physical vulnerability is concerned, and still be resilient in the aftermath of a disaster and manifest a high capacity to react and recover effectively. Also because what seems to emerge in literature is a different focus of vulnerability and resilience studies: the first are more oriented towards the identification of weaknesses, fragilities that make a given territory, a given community, a given country unable to resist the stress provoked by an "external" source. Looking at resilience we appreciate the capacities to react, to overcome the problems created by the same existence of vulnerabilities and to "bounce back" despite damages and disruption to ordinary life. Resilience entails the capacity to recover effectively, transforming the damage and losses into opportunities for a different territorial and environmental setting, in such a way that pre-event vulnerabilities will be reduced and the resulting societal, urban, and regional patterns are healthier and safer than before the event impact. Authors like Handmer and Dovers, 1997 and Norris et al, 2008 have rejected the idea that a resilient community or a resilient city is simply a community or a city that is able to bounce back to pre-event conditions. Sometimes getting back to the exact pre-event conditions is just the opposite of resilience, particularly when high level of vulnerabilities characterized that condition. Instead, resilience has to do with the capacity to adapt to changes, to manage creatively uncertainty, to find resources, both material and immaterial, to face the consequences of a disaster.

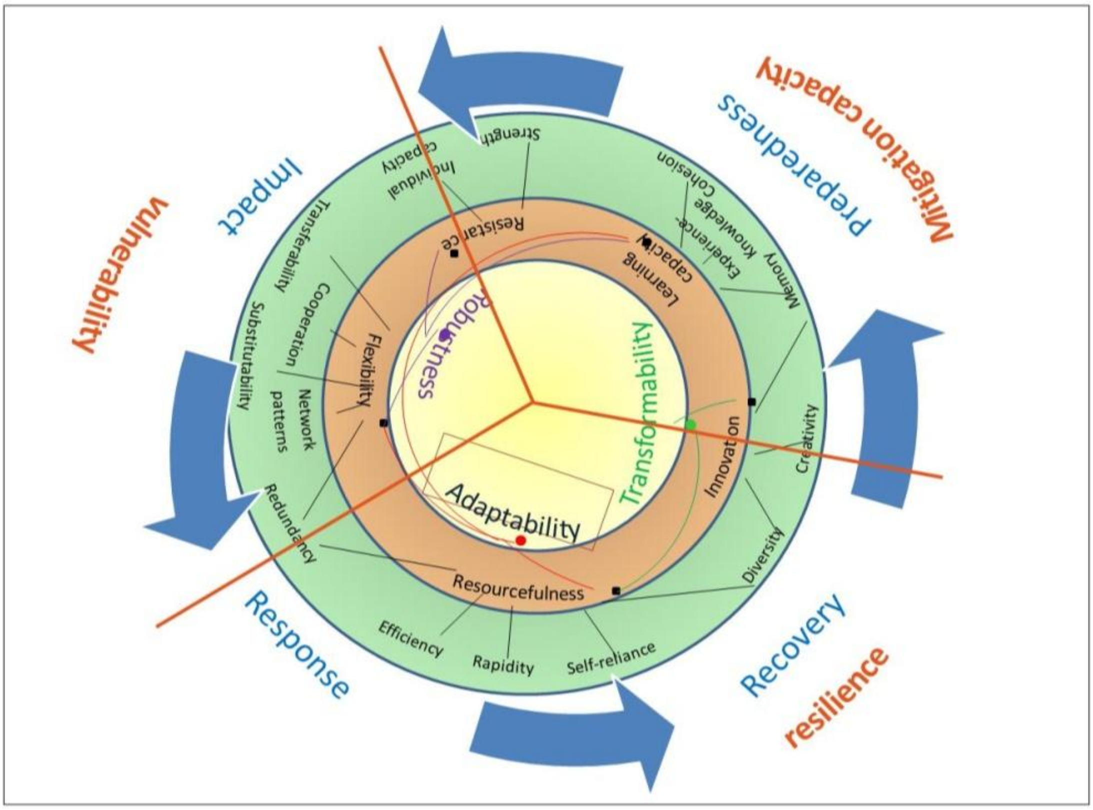


Figure 1.2: Diagram showing the conceptualization of vulnerability, mitigation capacity and resilience in the Ensure project

Resilience is perhaps an even more dynamic concept than vulnerability, in that it addresses the capacities to innovate and the ability to strategically orient complex processes like those implied by emergency, recovery and reconstruction.

As just mentioned, literature on resilience is as vast as that on vulnerability. Also in this case the Ensure project needed to choose a direction of work, an interpretation cutting across the various definitions and alternative views available so as to be able to include resilience in the integrated framework.

The diagram in figure 1.2, represents the interpretation provided by the project.

2 Methodological approach and framework description

The framework developed within WP4 represents the final output of a long process of reflection, discussions among partners, and was shared with external experts in a workshop hold before the 2010 summer (see second annex). It is an attempt to accommodate the various relevant aspects that have been shortly described insofar and which constituted the results of previous WPs. It also has the ambition to comprise some of the knowledge and information about resilience and vulnerability that has emerged from literature and previous projects.

The need to conceptualize the tools to be used in assessing vulnerability and resilience is strongly felt by the Ensure team. The large majority of articles and previous work simply couple theoretical thinking about the two (or more related) concepts and some applications where indicators and parameters are used (Eriksen and Kelly, 2007). Often it is not clear how the selected indicators are actually linked or derived from the most theoretical part. The associated risk is to use indicators that are taken for granted without further investigation that instead would be required. For example most studies consider the elderly more vulnerable, without making distinction within this rather large and too generically defined social group; in some instances (see Handmer, 2003), the elderly has performed much better than the younger generations, making evident that generalizations cannot be accepted without further analysis and that there is the need to relate indicators to specific spatial and temporal contexts before any convincing appraisal can be carried out.

A similar need had emerged at a certain stage within the field of sustainability, and the 90s were marked by a rather consistent work on methodologies to identify appropriate parameters and criteria for judging whether or not the latter were consistent enough and useful to understand to what extent a region, a city, a country were actually getting closer to a condition of sustainable development (see Mac Laren, 1996; Winograd and Farrow, and, Winograd, 2007). It is odd for us to see that until now at least, few articles have appeared in the same vein in the vulnerability and resilience arena, even though we are convinced that a season of a similar outbreak of studies on the validity of indicators chosen to assess vulnerability will open. There will be a strong need for such studies as vulnerability assessments will be increasingly required by legislation (as in the case of the Flood Directive) and will constitute basis to distribute resources for mitigation.

In summary, three answers can be provided for the legitimate question: why and what for a framework for vulnerability and resilience assessment.

First, within the framework the goals to be accomplished carrying out the assessment must be established. What for? How the assessment may help in finding ways to mitigate risk and better prepare for facing the consequences of events the residual risk of which cannot be eliminated?

Second, to "find the right place" for each indicator that is in any case used in currently adopted vulnerability assessment tools. Within the framework the questions we try to answer with each selected indicator have to be made explicit. In this way not only the questions at stake - but also the extent to which proposed indicators and their relative measures are actually providing a good proxy or synthesis of corresponding features and processes- become clear. In other words, are the proposed indicators (sometime driven by existing data) are actually representing the vulnerability aspect that we need to address?

Third, and more general answer: the framework represents a model that attempts to capture the most relevant features of vulnerability so as to permit to draw a satisfactory picture of a given place and community in terms of their expected response to the impact of an extreme natural event. In this respect, the framework shares with any other model the fate of being a selection of aspects that are considered as particularly relevant and representative of a given reality. Inevitably many things have to be left out of the model, which by definition cannot and should not be clone of reality, but a mean to make sense out of what is observed in the "real" world. As Slobodkin (1994, quoted in Bell and Morse, 2008) puts it:

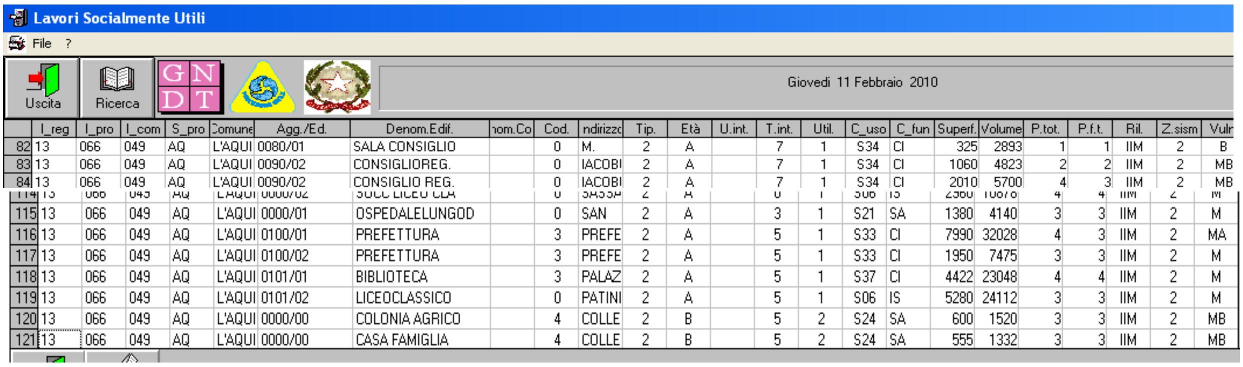
«Essentially all science is the study of either very small bits of reality or simplified surrogates of complex whole systems. How we simplify can be critical. Careless simplification leads to misleading simplistic conclusions».

2.1 Main Ensure objectives and methodological procedure

The Ensure project had set ahead two main objectives, one more general and theoretical and, the second more specific.

The more general objective was to provide an interpretation of the relationship between vulnerability and related concepts (resilience, adaptation, coping capacity, etc.) within a framework strongly finalized towards prevention, following the rationale described in the previous paragraph. The framework must provide a sort of guideline to assess vulnerability before an event strikes, helping decision makers and even lay citizens take appropriate mitigation and anticipatory measures. In other words we are not satisfied with tools that permit only ex-post analysis, leading to a detailed and well developed description of what happened in a given area stricken by an extreme event, we wished to be able to identify the weaknesses and fragility that combined with the severity of an event may lead in the future to damage and losses.

An example may clarify what is meant here. In the years 2001-2002 a rather interesting project was carried out by the Italian Ministry of Labour. In the context of social works for unemployed professionals with a master in architecture and civil engineering, it was decided to carry out an assessment of the seismic vulnerability of all public facilities (like schools, municipality buildings, governmental offices etc.) in Southern Italian regions. The final results is rather impressive, as there exist now records with fundamental data and assessments of the physical vulnerability to earthquakes of all facilities where a large number of people can be expected at the time of a seismic impact or that are critical to manage the emergency. Furthermore skilled professionals were trained in seismic construction, and were provided the capabilities to identify key vulnerability factors in buildings. L'Aquila was among the cities where the assessment was accomplished: several public buildings that collapsed or were severely damaged during the 6 May 2009 earthquake had been the object of analysis and ranked as very vulnerable (see figure 2.1). Were this information been used by authorities either to reinforce those structures or at least to check their residual resistance capacities after the first shocks recorded months before the main one, perhaps many lives could have been saved. Clearly what is apparent in this example is the potential utility of vulnerability assessments in very practical terms, but also the need to go beyond physical vulnerability to address the various deficiencies of complex social and environmental systems, that may lead to lack of compliance with norms and regulations, or to the poor management of information that holds the potential of saving lives and prevent the most severe losses.



	I_reg	I_pro	I_com	S_pro	Comune	Agg./Ed.	Denom.Edif.	nom.Co	Cod.	ndirizzo	Tip.	Età	U.int.	T.int.	Util.	C_uso	C_fun	Superf.	Volume	P.tot.	P.f.t.	Ril.	Z.sism	Vuln
82	13	066	049	AQ	L'AQUI	0080/01	SALA CONSIGLIO		0	M.	2	A		7	1	S34	CI	325	2893	1	1	IIM	2	B
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115	13	066	049	AQ	L'AQUI	0000/01	OSPEDALELUNGOD		0	SAN	2	A		3	1	S21	SA	1380	4140	3	3	IIM	2	M
116	13	066	049	AQ	L'AQUI	0100/01	PREFETTURA		3	PREFE	2	A		5	1	S33	CI	7990	32028	4	3	IIM	2	MA
117	13	066	049	AQ	L'AQUI	0100/02	PREFETTURA		3	PREFE	2	A		5	1	S33	CI	1950	7475	3	3	IIM	2	M
118	13	066	049	AQ	L'AQUI	0101/01	BIBLIOTECA		3	PALAZ	2	A		5	1	S37	CI	4422	23048	4	4	IIM	2	M
119	13	066	049	AQ	L'AQUI	0101/02	LICEOCLASSICO		0	PATINI	2	A		5	1	S06	IS	5280	24112	3	3	IIM	2	M
120	13	066	049	AQ	L'AQUI	0000/00	COLONIA AGRICO		4	COLLE	2	B		5	2	S24	SA	600	1520	3	3	IIM	2	MB
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Figure 2.1: Detail from vulnerability assessment records for the city of L'Aquila

Within the project the result corresponding to this more general objective is the integrated framework shown in figures 2.4 and 2.5 and described in detail in paragraphs 2.2 and 2.3.

The more specific goal of Ensure was to advance in the most "established" field of vulnerability assessment, providing an updated picture of what is already available in literature, in previous studies, and in applications worldwide. We may count already on a good number of proposals concerning vulnerability indicators, parameters and measures, related to physical, systemic and social aspects. Those have been analysed and a selection of what seemed to the working group as most advanced or appropriate was proposed as part of the tool for vulnerability assessment. The result of this more specific goal can be seen in the individual matrices that are part of the integrated framework, as described in paragraphs 2.3 and 2.4.

From a methodological point of view, the seismic case was selected as a reference example. In the latter in fact, methods for assessing buildings vulnerability to ground accelerations provoked by seismic waves at a given site have been developed for at least the last thirty year, producing results that are reasonably shared by the scientific community. From a theoretical perspective, the methodological path that has been followed is of particular importance to us (figure 3). It can be conceived as a four step path organised as follows:

- First damages have been surveyed and analysed to identify what were the mechanisms leading to specific failure patterns. Surveyed damage buildings are now part of a huge database comprising thousands of cases.
- The large number of surveyed buildings allows for recognising recurrent failure patterns that are related to structural and non-structural characteristics that can be considered as an integral part of the failure mechanism, being the other relevant components the seismic input. Long years of study and discussions have led to the selection of a restricted number of indicators, summarizing the fundamental aspects that can be deemed as responsible for a given structural response, like shear resistance, plan and facade regularity. Those indicators serve as references to check the capacity of any regular structure to withstand the stress provoked by seismic shocks.
- Then the picture provided by the vulnerability assessment tool must be compared to the real damage when the latter unfortunately occurs during an earthquake. Fragility or vulnerability curves represent the result of the procedure correlating the level of damage to the earthquake intensity or acceleration as can be seen in figure 3: to moderate levels of stress resistant buildings suffer no or minor damage while vulnerable ones are already significantly affected. At increasing levels of stress, vulnerable buildings collapse, while the least vulnerable still show residual resistance.
- The last step requires refining vulnerability assessment tools and indicators any time new information or understanding of structural seismic response is available after damage surveyed in a real event.

Parameters to assess buildings vulnerability to earthquakes (GNDT)

Parameters	Classes A	B	C	D	weight
1. Type and quality of structural components	0	5	20	45	1.0
4. Building	0	5	25	45	0.75
6. Plan layout	0	5	25	45	0.50
7. Front layout	0	5	25	45	variable
8. Distance of walls	0	5	25	45	0.25
9. Roof	0	15	25	45	variable
10. Non structural components	0	0	25	45	0.25
11. State of maintenance	0	5	25	45	1.00

Data comes from surveys conducted by instructed personnel

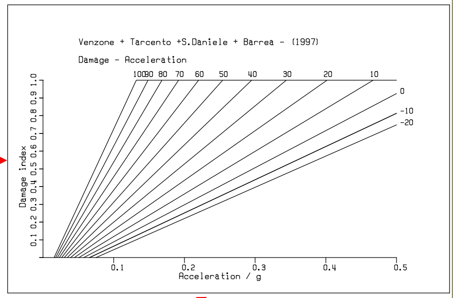

Figure 2.2: Methodological process for eliciting physical vulnerability parameters in the seismic case

Ideally this methodological path can be followed also as far as the vulnerability of structures to other types of stress (floods, landslides, fire, etc.) is concerned and experimental fragility curves have been proposed. Such methodological path can be seen as more general, not only for physical damage and physical vulnerability but as having a more general validity. The analysis of damage occurred in a severe event should lead to identify what "part" of the damage can be attributed to the weakness of the affected system, to its inherent characteristics, making it more prone to suffer damage with respect to similar cases in the same event or in similar situations.

By this we mean that also failures that cannot be labelled as physical structural performance can be analysed adopting a similar approach. What would be needed is a detailed reporting of malfunctioning in services, utilities, and critical infrastructures, the cause of which is due in part to the physical stress, but also (sometimes mainly) to weaknesses arising at the complex interaction of components and systems.

In this regard it can be said that the proposed framework may be beneficial not only for conducting vulnerability assessment but also as a guidance to produce better damage accounts than has been the case until today. Some types of damage (in particular indirect, secondary, induced) have been scarcely reported, while the attention of authorities go to the costs of reconstruction ignoring the ripple economic and systemic effects that may reverberate across regions and communities. Those damages, generally underreported, may be nevertheless very relevant in explaining subsequent patterns of vulnerability long after the hazard impact and in areas apparently remote from those actually hit.

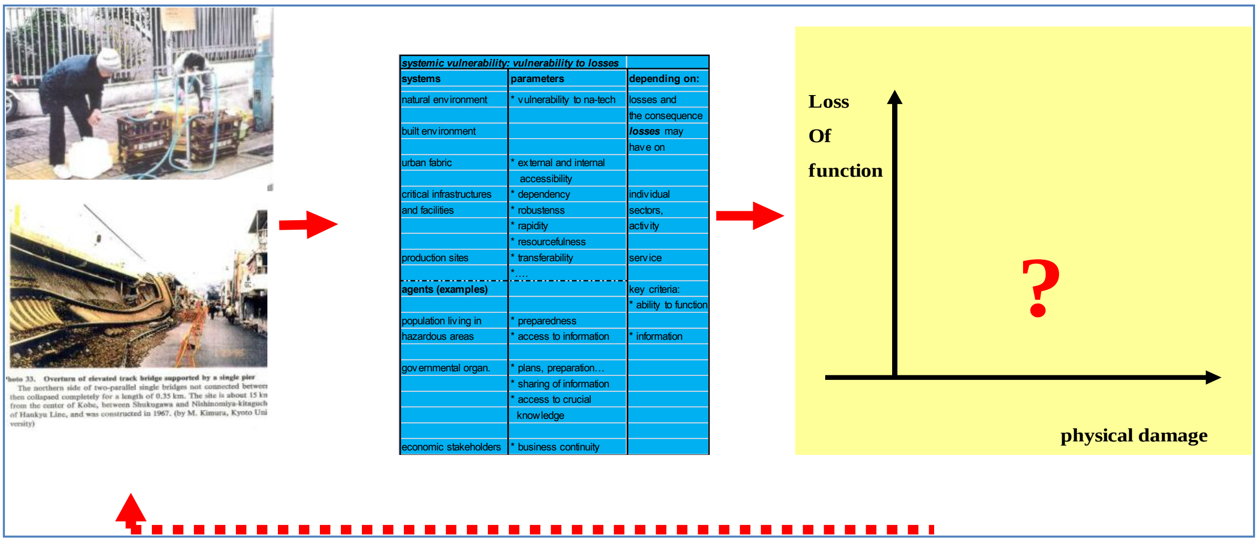

Figure 2.3: *Methodological process for eliciting systemic vulnerability*

The goals that have been described entail a rather high complexity, representing a challenging endeavour for the project. It is therefore hard to imagine that they can be accomplished in a single phase or following a strictly top down approach. Instead a more pragmatic procedure has been adopted: a mixed top-down and bottom-up path have been followed. Several case studies have been analysed in the previous WPs of the project with the idea of extracting significant aspects and concepts that could make part of a framework with a more general validity (that is not strictly linked to the individual case study); on the other hand, once developed, the model has been applied to the test case study areas, so as to get feedback regarding what had to be changed and how in the framework.

The present report has been re-written at least a couple of times, to include "lessons learnt" from the initial application of the method. Such an iterative process has been followed also by other scholars pursuing similar objectives, representing for us a "relieving" reference (see Polsky et al., 2007).

2.2 Description of framework for integrated multiscale assessment of vulnerability and resilience to natural hazards

The framework responds to the requirement of general theoretical advancement that was one of the two main objectives of the project. Combining the different pieces of the puzzle (or what can be recognised as such) into a methodological framework comprising the various aspects that were deemed important by the working group is by no mean a minor result, even though we are aware of the long way ahead before all parts of it will be actually operationalized in a satisfactory way.

In figure 2.4 the framework is shown: as it can be clearly seen it is deployed over a plan where both the spatial and the temporal dimensions are evidenced. As for the spatial one, the scales at which both hazards and vulnerabilities should be appraised are represented in two distinct axes.

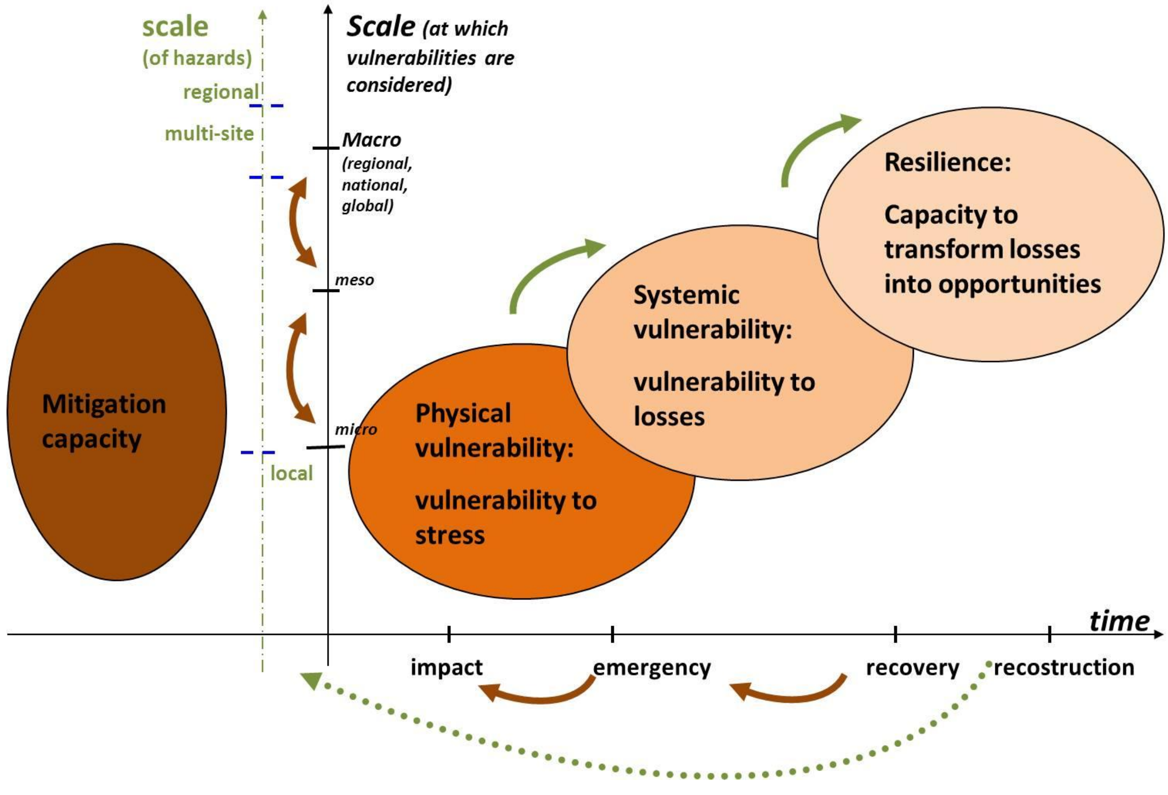

Figure 2.4: General representation of the integrated framework to assess vulnerability and resilience across time and scales

The reason is that not necessarily the scales at which hazards have to be analysed correspond to the scale at which the different types of vulnerabilities must be considered. For example, physical vulnerabilities are mainly addressed at the local scale, as the intrinsic fragility of structures, infrastructures, and people must be looked at in detail at the local scale. What appears at larger scale is the result of such analysis, in terms of comparison among places. As already mentioned, systemic vulnerability can be appropriately considered only linking the local to the large scale (provincial or county level to the regional and sometimes above regional). When it comes to consider the capabilities to recover effectively in a resilient fashion, all scales must be considered: what will be reconstructed is ultimately what has been locally damaged, but the needed resources cut across all levels of government and depend also on the type and strength of relationships among the affected places and a much wider region.

As for the temporal dimension, again, timing of hazards and vulnerabilities may differ: for example, the possibility of new occurrences of extreme events within a short period, when recovery is still going on, must be accounted for.

In the figure, it is shown how the various vulnerabilities and resilience are considered with respect to the phases of the disaster cycle. Before the impact, that is when a sufficiently long time has passed since the last big event, the mitigation capacities are considered. Rose (2004) suggests that it is more correct to talk about mitigation capacities in the period before the hazard impact, while resilience should define more appropriately capacity to recover from an extreme event. This is nevertheless a matter of deciding the most suitable definition; what is actually relevant here is the attempt to understand whether or not conditions to enhance coping capacity and resistance of a complex system exist or not and how they are manifested. At the impact, instead, the physical vulnerabilities play the major role: the direct physical damage that can be accounted for are strongly correlated on the one hand to the severity of the hazard, on the other to the level of physical fragility of artefacts and constructions. As the time from the impact passes, other forms of vulnerability gain relevance and, in particular during the emergency phase, precisely systemic vulnerabilities. Those express the response capacity (or lack of) not to the direct extreme event impact but rather the consequences of the latter, to the impairment in crucial systems and their components provoked by the physical damage. Finally, considering the time of reconstruction and recovery, resilience gain prominence: here again the response is not to the stress, but to the longer term induced, indirect, secondary effects it has produced. What we want to measure here is not merely a response capacity, but rather whether or not systems is able to recover by reducing pre-event vulnerabilities, to learn from the weaknesses that the event has revealed and to transform reconstruction into an opportunity to build and develop a better, safer and healthier place to live.

The red and green arrows represent the various connections and links that exist among the different types of vulnerability and resilience, in space and time. Those will be tackled in sections ahead.

2.3 Short description of the set of matrices comprising the framework

In this paragraph the ellipsoids' content as represented in figure 2.4 will be discussed in detail. Actually each ellipsoid is translated into a set of matrices as shown in figure 2.5.

In each matrix the vulnerability indicators are proposed, taken from literature, ongoing and past research carried out by the Ensure team.

In the first set of matrices, the capacity to mitigate is addressed; this means concretely that the vulnerability of the natural environment, the characteristics of the hazard are known, mapped and monitored appropriately. With respect to the vulnerability of objects and artefacts what is checked here is whether or not vulnerability assessment has been carried out and taken into consideration in planning and risk prevention policies; in the case of critical facilities, not only the awareness of systemic vulnerability is addressed but also the capacity to reduce it in ordinary maintenance programs should be envisaged and new facilities or replacement of existing ones must be considered. With respect to agents, their awareness of existing threats and fragilities is assessed as well as their willingness/capacity to address them when the hazard does not seem to impede in any particular fashion and time has passed since the last catastrophic event.

In the second set of matrices, the physical propensity to damage of the natural environment, objects, critical facilities and people is assessed. All factors that may increase the potential damage are considered, including the possibility of enchained effects, both between natural hazards (like for example landslides triggered by earthquakes) or between natural and vulnerable built systems (like for example na-tech).

In the third set of matrices, the potential reaction to first level losses is addressed: secondary effects in the natural environment, like for instance lahars or debris flows consequent to fires denudating entire slopes is considered. With respect to artefacts, urban areas and critical facilities, the capacity to keep functioning despite some level of physical damage is evaluated, considering the interdependencies among systems and among components of vital systems. With respect to agents, the capacity to manage emergencies, to endure in time of limited facilities and restricted access to resources and markets is considered.

Finally, in the last set of matrices, the recovery potential is appraised. As for the natural environment the ecological resilience is referred to, particularly for those hazards like fire or drought that may significantly disrupt the natural environment itself with permanent damage. For buildings and cities, the capacity to embed the lessons learnt in the disaster while reconstructing artefacts and places is evaluated, as well as the capacity to couple the physical reconstruction with the symbolic one, accompanying the healing process of a traumatized social system.

Regarding the latter, access to resources for reconstruction, availability of good administrative procedures, fast delivery of compensation are elements that seemed particularly relevant to recover in a satisfactory way. Fast access to compensation need not to be taken as an isolated indicator: the capacity to couple it to the control of how reconstruction will proceed and to what extent pre event vulnerabilities will be addressed is equally, if not more, important.

In this respect, but as a general consideration for all set of matrices, indicators should not be considered as standing alone. Some must be appraised in conjunction with others in order to draw a vulnerability and resilience assessment of a given area and environment.

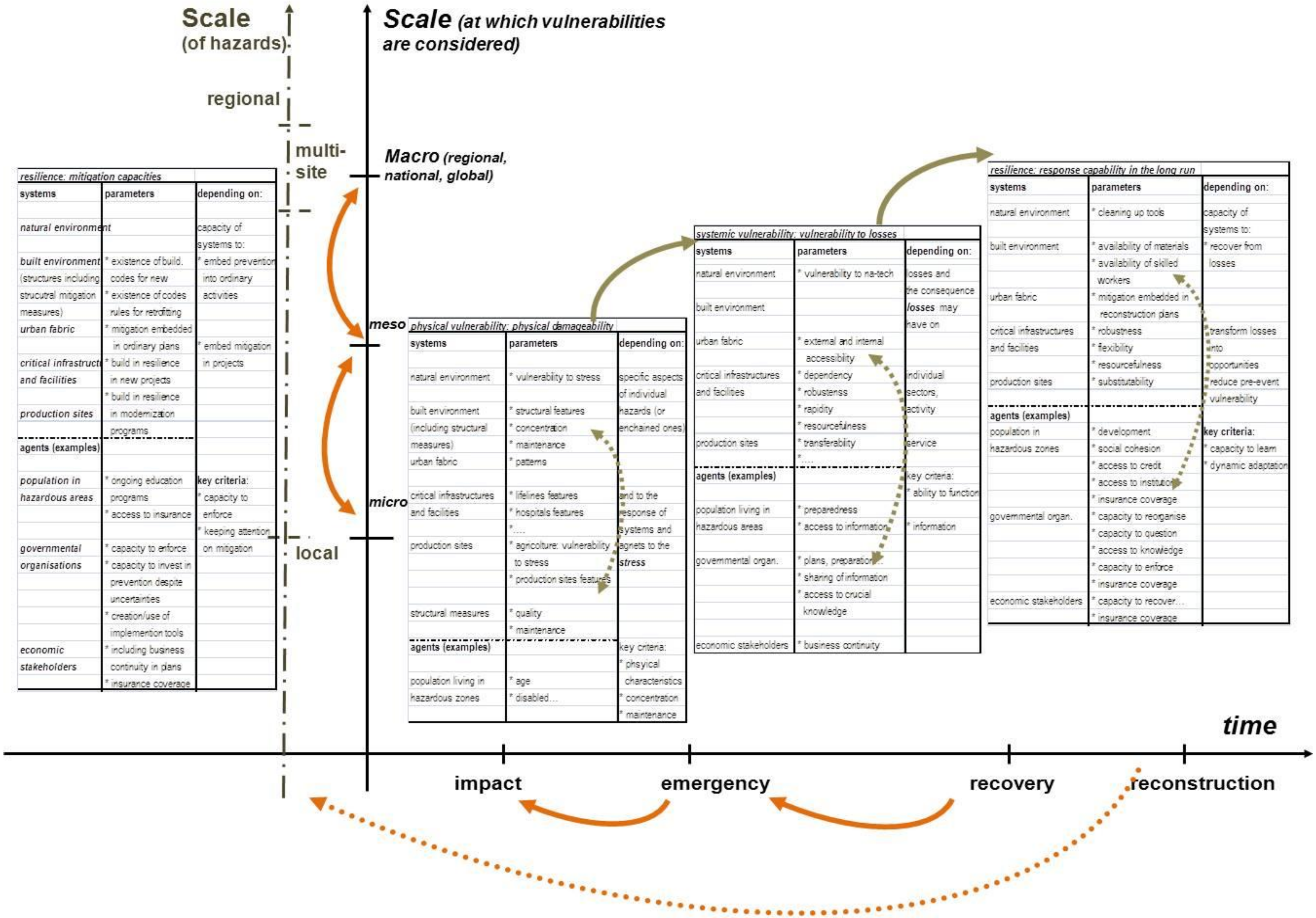

Figure 2.5: Ellipsoid translated into a set of matrices

Each matrix is in its turn divided in four sections or sub-matrices (see figure 2.6).

a. The first relates to the natural environment. Indicators that can be found in this part respond to three main questions:

   a. Is the available knowledge, including its representation in maps, tables, and other forms, sufficient and sufficiently taken into account for decisions at each stage of the disaster event?
   b. Are enchained natural hazards considered in the hazard assessment? It should be noted that this and the previous question are not aimed at introducing surreptitiously hazard aspects into vulnerability analysis. Instead the point that is made here is that a given system is less vulnerable if hazards are well known, monitored and early warning systems are put in place when relevant.
   c. Finally there may be elements in ecosystems and in environmental settings that are particularly vulnerable to the consequence of an extreme event (this is particularly true for forest fires and droughts) or to the mitigation measures which are taken to protect some other systems (for example lava diverting systems to protect buildings and infrastructures that may lead to the destructions of forests).

b. The second relates to the built environment. In this part of matrices the following aspects are considered:

   d. Whether or not buildings have been built according to specific norms or to state of the art considering previous lessons learnt from past disasters. On the other hand, the position of buildings within hazardous zones has to be assessed. Clearly this is more the case of an "exposure" rather than a vulnerability factor.
   e. For public facilities, the question is if there are further vulnerability factors that must be accounted for, regarding internal machinery, assets, tools that are fundamental for the functioning of a given service.
   f. As for the urban fabric, the point at stake is whether there are some vulnerability factors arising at the urban scale, going beyond the simple sum of the vulnerability of individual buildings and infrastructures, and which relate to the shape of the urban patterns, to the relationship between open and built spaces and with accessibility.

c. The third regards critical facilities and production sites that are considered separately because of their importance in guaranteeing the survival of an urban system and for the well being of the potentially affected community. From a theoretical point of view they may be seen in conjunction with the vulnerability of the built environment, but from a practical and strategic perspective it makes sense to separate them. Critical facilities gain their prominence when systemic vulnerability must be appraised.

d. The last part is devoted to the assessment of social systems and economic stakeholders' vulnerability. Social systems' and agents' vulnerability has been considered with respect to three main sub-groups:

g. Individuals vulnerability, related to the level of awareness and preparedness to both mitigate and face the consequences of an external stress;
h. Institutions' vulnerability, in which all agencies and organisations that may have a key role in both disaster management and disaster avoidance are considered.
i. Finally economic stakeholders, who, similarly to institutions, may have a leading role in shaping vulnerability, in creating coping capacity mechanisms.

System	Component	Aspect	Aspect parameter	Criteria for assessment	Comments/ case study
Natural environment	natural hazards	existence and quality of mapping and monitoring	Specific parameters to permit assessment of the aspects that have been identified as relevant	Criteria may range from binary (yes/no) to degree (corresponding to judgements) or to more physical measures (for example related to time needed for ecosystems to recover)	Specific parameters to permit assessment of the aspects that have been identified as relevant
	enchained events	assessment of hazards triggered by other hazards			
	ecosystems	fragility to hazards and to mitigation measures			
Built environment	residential buildings	existence and compliance with codes and land use planning regulations	Specific parameters translating into measurable factors the aspect to be assessed	Criteria for multiple measurement modality are provided; they also depend on the scale at which the assessment is carried out	Building codes exist for some hazards (particularly seismic) and not for others; nevertheless research in the field of resistance assessment to various types of stress has evolved in the last decades
	public facilities	existence of vulnerability assessment and their consideration on mitigation strategies or in emergency plans			
Infrastructure and production site	critical facilities	existence of strategies addressing the interdependency and the functioning of critical facilities under extreme conditions	Parameters to specify conditions at which crucial lifelines and utilities cna keep functioning are provided, as well as to address the potential for na-tech	Criteria for assessment are provided; proposed criteria reflect the need to address the interaction across spatial scales of such facilities	Critical facilities and production sites are clearly part of the built environment. Nevertheless a specific group of rows have been dedicated to them because of their relevance.
	production facilities	existence of plans and procedures to maintain production in safe conditions given the possibility of an extreme event			
Social system (agents)	people/ individuals	weaknesses versus preparedness of individuals	Most of those are qualitative parameters to assess the general level of preparedness and recovery capacity (or lack of) to traumas and discomfort provoked by potential disasters	Criteria for evaluating the parameters are provided, taking into consideration the different spatial scales at which individuals, institutions and economic agents act	Whilst the previous groups of systems relate more to the "physical environment", clearly this one embeds the results of decades of social sciences research in the field of risk and disasters studies
	community and institutions	weaknesses versus preparedness of organisations and institutions			
	economic stakeholders	preparedness and recovery capacity (or lack of) economic stakeholders			

Figure 2.6: Matrices structure

With the rather broad term of social vulnerability we address several components of societal coping capacity, ranging from individuals, to social groups, to communities, to organisations. Social vulnerability can be both physical and systemic, as people can be physically injured and harmed, but are also vulnerable to the lack of basic services, to the new conditions required by evacuation, temporary sheltering, et. In the same vein, organisations, like for example civil protection, can be harmed in their assets and personnel, or diminished in their capacity to react because of a variety of systemic failures, including the lack of coordination and collaboration among different agencies, problems in communication, problems in deciding about matters that hold significant juridical and moral challenges. An important distinction that has been introduced in WP2 is between social and human capital, intending that vulnerability of both should be appraised. For neither of these concepts universally accepted definitions can be found. Basically, we can assume that human capital refers to skills, dexterity (physical, intellectual, psychological) and judgement capacity, which may be lost during an extreme event; on the other side, social capital refers to the value of social networks affecting the productivity and capability of individuals and groups to cope and recover from an extreme event.

With economic vulnerability we refer to the response that economic sectors are able (or unable) to provide in the aftermath of an extreme event. Also in the case of economic vulnerability, both physical and systemic aspects must be considered. Economic assets can be physically damaged, but economic activities are clearly extremely vulnerable to interruption of transportation services, to deficient lifelines, etc.... Days without the possibility to work, to receive products or to send them to destination constitute a net damage measurable in monetary terms.

As can be seen in figure 2.6, each matrix is organised in columns:
- The first identifies the system to be assessed;
- The second identifies the components of the systems;
- The third clarifies the aspects that have to be considered in the choice of the indicator/parameter that may better respond to the question, shown in the third column;
- The fourth and the fifth determine how indicators/parameters can be measured and assessed, upon what criteria and using which tools (maps, diagrams, scores).
- In the last column references are made either to a case study that was analysed in detail or to several cases that are relevant to the specific indicator at stake.

It has been decided to produce a set of matrices for each "hazard" (see figures 9 to 13). Methodologically it seemed useful to check to what extent the individual parameters in each set of matrices had to be differentiated upon the expected threat. In fact not only the physical response to the stress is so to say dependant on the hazard type of forces and/or pressures exerted on structures. Each hazard may vary as far as duration of onset (sudden or creeping), location (point or area- shaped) are considered: those aspects must be taken into consideration defining monitoring and mapping systems as well as specific mitigation measures to be taken before and after the impact.

This does not mean that a multi-risk perspective is not considered. Actually it is pursued in two ways. First, in each set of matrices the possibility of enchained events (hazards triggering other natural or technological threats) is fully appraised. Second, in applications (see WP5), a set of matrices related to the hazard threatening a given area can be used in combination. Results of applications to the test case studies confirmed that not only the physical vulnerability matrix is somehow "hazard specific". An area, a community can be for example very well equipped and prepared for some events, while underestimate other hazards to which it is exposed.

2.4 Working with vulnerability and resilience indicators

As already mentioned, few studies have attempted insofar to clarify how different types of vulnerabilities should be accommodated in one integrated study and what process should lead to the identification of suitable indicators. Studies in this regard can be found regarding sustainability indicators and reports for countries or urban areas (see in particular MacLaren1996; Winograd and Farrow, n.d.). Those studies discuss the criteria that should drive any effort to develop sustainability indicators. The latter are rather useful for the present project, as the concept of sustainability is as difficult to measure as is vulnerability. Both require to capture the complex interrelationship among different systems which interact at various spatio-temporal scales, in a parallel and even in a cross cutting fashion.

One important difference seems to distinguish vulnerability from sustainability: while in the latter the verification process is extremely difficult, as it requires confronting the state and the process toward sustainability with impacts that cannot be fully envisaged, in the case of vulnerability indicators, the latter can be confronted once an extreme event occurs with actual damages. This is perhaps more true for physical, some kind of systemic, social and economic vulnerabilities than for others, in particular resilience parameters. At least in principle, though, it is possible to compare the vulnerability assessed before the event and the damage occurring afterwards as well as to compare the expected response capacity with the way an actual event has been managed. In the meantime the establishment of good vulnerability indicators permits to enlighten aspects and types of losses that should be considered and checked in any event aftermath, so as to gain a reference value against which the validity of vulnerability indicators and of key measures can be evaluated.

This means that the distinction between different kinds of vulnerability should encourage estimating coherently damages, distinguished among physical damage to buildings and infrastructures, damage to economic assets and activities, losses to human and social capital, secondary consequences in terms of functional failure of fundamental services an activities.

On the other end, studies which are currently addressing the issue of how to find the best fit vulnerability indicators are being developed in the climate change community (see for example Eriksen and Kelly, 2007, Adger et al., 2004). Those studies are particularly enlightening in that they drive our attention to the need to capture complex processes and relations among indicators, and not just provide a state diagnostic, which may be limited in relevance as far as potential usefulness by end users and decision makers.

Therefore, before entering into the discussion of the validity of each individual parameter that has been selected, the criteria that have driven the same choice should be discussed.

The latter can be synthetized according to the diagram shown in figure 2.7. Criteria are grouped along three main axes:

- On the x axe, the inherent characteristics of indicators are addressed;
- On the y axe, the characteristics of the data to be used to assess the indicators value in a given place are shown;
- On the z axe, the usefulness of indicators is appraised.

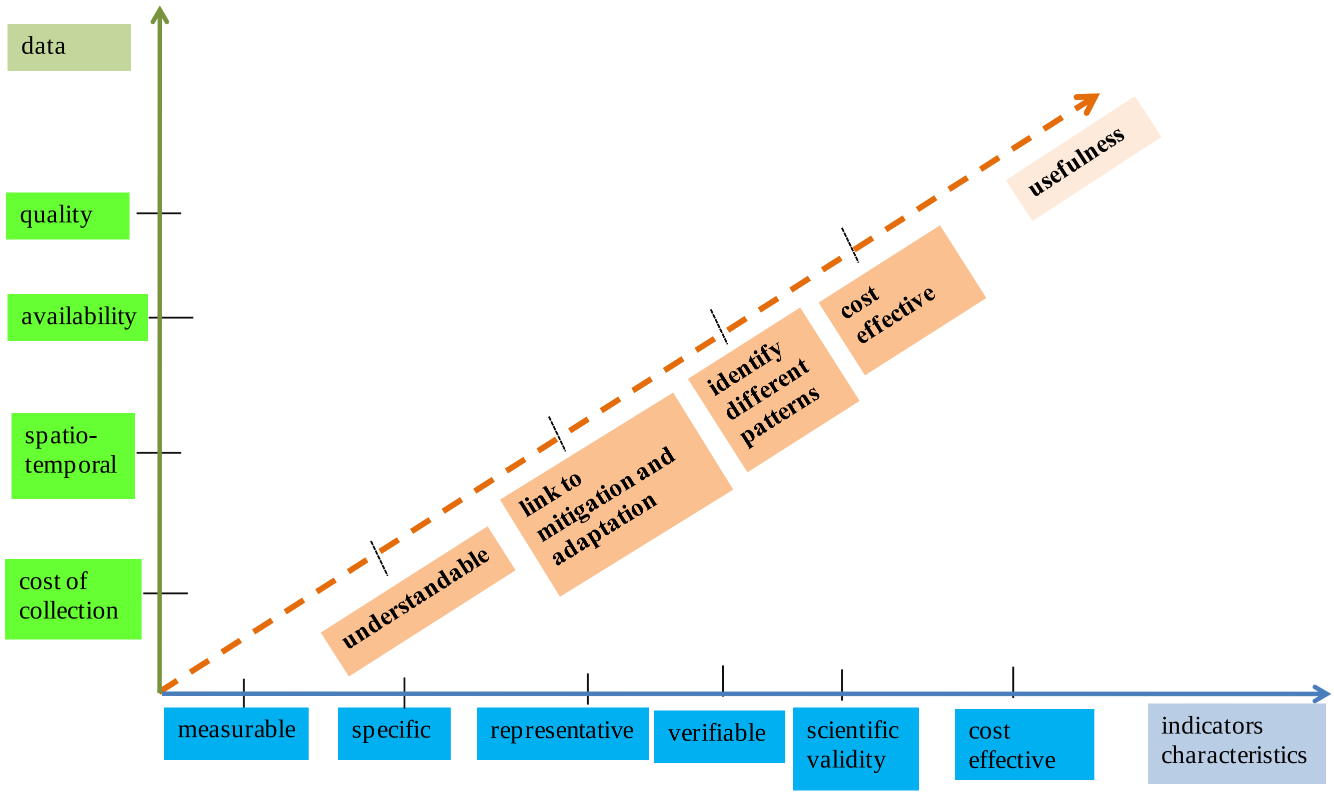

Figure 2.7: Criteria to identify and select vulnerability indicators

a. With respect to the inherent indicators characteristics, the following have been granted importance in the literature.

- **Measurability**. We are aware from the work that has been carried out in previous WPs that the complexity of phenomena and societal response to natural calamities cannot be fully grasped just using indicators. In the meantime we believe that the latter should be intended as proxies of complex aspects and systems' characteristics, so as to be able to achieve some important goals. The first is comparability among places and communities, to establish priorities and identify key specificities as well as constant features; the second is the possibility to assess, though with large uncertainties, to what extent given policies and strategies are able to move the system towards increasing or decreasing vulnerability levels. By measurability we do not intend only quantitative measures, but also qualitative, which allow constructing some sort of qualitative grouping of values referring to a benchmark or value established by previous research and findings.
- **Specificity.** Indicators should address as much as possible specific vulnerability aspects rather than generic features that do not help in understanding what makes a given area or a

given society more or less prone to suffer the consequences of an external stress. As mentioned in a previous deliverable, for example, economic disadvantage is not per se a measure of vulnerability: it becomes such when we are able to demonstrate how a poor response and low coping capacity is linked to limited access to financial resources and to services.

- **Representativeness**. Indicators should represent a wide set of cases and situations rather than being constructed after each individual case. This requires that indicators are chosen after they have been recognised as constant elements in several similar cases or across scales and regions or across different risks. Indicators cannot be too tailored to the specific case at stake, even though calibration procedures must be carried out; on the other hand, they must guarantee a minimal level of generalization, to be supported by statistical analysis. While this requirement can be met for physical vulnerability, it is far more complicated and thus constitutes more an aim than an established feature, for the less investigated aspects, like social, systemic, and economic.
- As for **verifiability**, as mentioned at the beginning of this paragraph, there is the need to tune the search of correlations between indicators and surveyed damages after disasters, so as to be able to improve the capacity of indicators to elicit those systems characteristics that seem to be the root causes of poor or mediocre response.
- The features mentioned above can be all mentioned as part of **scientific validity**, particularly when we talk about measurability and verifiability. In the meantime, to be scientific, indicators should meet the agreement of a large scientific community, should strive toward objectivity, even though we are all aware about the large room for subjective and even arbitrary judgement that is inevitably involved in any complex environmental assessment requiring to bridge among natural and human systems. Nevertheless, what can be required is that indicators be chosen as rigorously as possible, be framed in a transparent conceptual framework linking the selected indicators to the notion that must be evaluated (in our case vulnerabilities).

b. With respect to data characteristics, the following criteria should be met, while looking for vulnerability indicators:

- **Data quality** is an important requirement, even though many times only poor quality data are available, particularly for indicators that are not part of a long and well established tradition. In this case, perhaps it can be recommended that at least the quality of data will be made explicit so that assessors can judge to what extent the related indicator can be considered reliable. In fact, in designing a general framework, it is rather hard to dismiss all indictors for which data are not available in a given country or region good: this would be too limiting, also considering the fact that data quality differ enormously from one region to another and sometimes even from one municipality to another. Therefore eliminate indicators on this basis would diminish the relevance of assessments also in areas where data quality is high and the information that can be obtained may be very valuable for mitigation purposes.
- Indicators of vulnerability are required to cover different spatio-temporal scales, when this is relevant for the final assessment. In this regard, we should make sure that data are available accordingly at the needed **spatio-temporal scales**. Similarly to what has been

said for data quality, this requirement, while valid in principle, can prove to be too limitative in some situations and particularly currently, as many data are not available because they have never or poorly been considered until now for risk mitigation purposes. As said above, the framework and the proposed indicators should set a sort of pathway for future damage assessment, to capture the attention of analysts on aspects that have been neglected insofar.

- **Availability** should be considered also **over time**, particularly when processes must be captured: data that are available only at a given time spot do not permit to follow processes or to monitor whether or not a given system is becoming less or more vulnerable over time.

c. The entire method is being designed to guide and orient amidst mitigation strategies. In this respect, how useful proposed indicators are in enhancing the latter must be asked as well. Usefulness in this regard does constitute an important criterion for indicators selection.

- The first requirement is that indicators be **understandable** by users, not only as far as terminology is concerned, but also in the way they are measured, reference values selected and actually used in the assessment. This is a fundamental requirement; should indicators be discussed with concerned stakeholders and be used by them as part of their ordinary planning in programming activities (of land use and spatial planning, granting permissions, deciding about infrastructures modernization etc.).
- Indicators should provide directly or indirectly a door towards a set of strategies aimed at mitigating present levels of risk. In this regard they should not be only "descriptive" of a given situation, but also be **linked to potential intervention policies**, both as goals to be achieved and as factors against which achievements can be monitored and appraised.
- Perhaps the most important requirement with respect to all those defined insofar, relates to what extent proposed indicators permit to **distinguish different patterns** in a given areas, eliciting so called "pockets" or hotspots of vulnerability. In general, it is an important requirement that using the indicators, differences among conditions, individual areas, zones, parts of community, and communities are sorted out, so that priorities can be decided and tailored measures designed.

The "**cost effectiveness**" requirement has been left at the end to be considered collectively across all axes.

Talking about data collection, cost effective means that a reasonable cost is associated to the operations needed to gather the required data. In this respect it is commonly known that census data, data derived from national and international databases are often preferred, not only because they are cheaper, but also because they guarantee coverage over time and across scales, and can be used for comparative purposes. A balance must be obtained between the requirement of good quality data, optimised for the needed level of detail, and cost of collection.

Talking about usefulness, indicators that require too complex mechanisms to obtain data, or data that are privately hold or covered by secrecy are of limited use.

Finally cost effectiveness can be measures also from a cognitive viewpoint: indicators that are too complex to construct, that require sophisticated and opaque operations to be assessed should be carefully considered, given the large uncertainties they may entail. In the meantime, also the total number of indicators must be the object of reflection: endless lists of indicators are not only difficult to use, but also raise questions about the actual possibility to guarantee the other requirements of quality and usefulness that have been described until now. From a cognitive point of view, sustainability studies warn against the excessive number of parameters that nobody is able to neither handle nor master.

2.5 Example of the tailoring of matrices to a specific hazard (forest fires)

In order to fully grasp the characteristics and the potential of the proposed method, an example of the application of the framework to the forest fires case will be illustrated. In the first matrix, the mitigation capacity in a given area is examined (table 2.1). In the first section, related to the natural environment, the key issues to be considered refers to the existence of hazard maps and particularly of early fire detection systems connected efficiently to triggers able to mobilize resources for firefighting on the one hand and the protection of the population on the other. In the meantime the vegetation characteristics are assessed as far as their inflammability is concerned. In the built environment section, the main questions refers to whether or not existing vulnerabilities are recognized and addressed in land use plans and in urban strategies, related to ordinary residential buildings and to public facilities.

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Paramters value/ categories	weight	score	scale	Comments
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard maps availability	Maps of areas prone to fires; map of inflammability of vegetation	yes/no; quality as judged with respect to international standards	1		At both municipal and county or regional levels	In many cases hazard maps are available; the point though is also to understand to what extent they are fit to support mitigaton strategies
			Do hazard assessment consider climate change	binary	yes/no	0,5			
		Available knowledge updating	Hazard maps updating	Frequency of updating	every 2 years and after each event/rarely	0,5			
		Hazard monitoring systems	Existence, distribution and quality of monitoring networks	technical monitoring systems linked to operation centre	yes/no	1			
				permanent staff dispaced in critical areas for direct monitoring and immediate intervention	yes/no	0,5			
		Connection of monitoring devices to modelling systems	Availability, quality of early detection systems and models	binary; quality of early detection and propagation estimation models	yes/no; models tailored to the geographical context/not tailored	0,5			Technologies and models to predict phenomena must be tailored to the sepcific context to be effective
		Structural defence measures	Existence of defenses for breaking the fire lines	binary	yes/no	1		At municipal/ county level	
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	binary; updating frequency	yes/no; every time new building permits are given/only occasionally	1		At municipal / county level	
			Risk maps and scenarios, including enchained events	binary; year of production	yes/no	1			
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations and specific requirements	1			In most cases vulnerability assessment are not available; but even in cases where they are it is important to check if they are considered in planning decisions
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	binary; updated	yes/no; rules efficacy checked after each event/rarely tested	0,5		At national / regional levels	
			Property regime of houses	owned houses versus tenants	owners ow < 50%/ ow > 80%	0,5		At municipal/ county level	In literature it is hold that private owners may be more willing to take mitigation actions
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	yes/no; judgement about the capacity to conform to the "code of practice"	0,5			
			Maintenance of fire suppression devices and clearing vegetation around houses	binary	yes/no	1			
			Land use plans embedding risk mitigation and vulnerability reduction	binary; specific indications for vulenrable locations	yes/no; specific rules for the wildland-urban interface and for accessibility	1			This parameter has to be considered together with the previous ones on quality of hazard maps and on inclusion of vulnerability assessments
			If previous paramters yes, then Implementation capacity	binary; frequency of inspections; trained personnel for inspections	yes/no; every year/seldom	1		At county/ regional or national levels	Implementation is a crucial aspect, inorder to translate mitigation decisions into risk reduction actions
			If previous paramters yes, then Integration to other measures (insurance)	binary	yes/no	1			Insurance per se can be even counterproductive in terms of mitigation, unless premium is set considering actual risk

Table 2.1.a - Matrix to assess mitigation capacity to forest fires

Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary, particularly for roads and water for firefighting	yes/no	1		County/ regional level	
			Maintenance programs embedding mitigation	binary	yes/no	1			For critical infrastructures it is not likely that complete substitution will take place just for risk prevention purposes; therefore it is crucial that in future plans and maintenance programs prevention will be one of the criteria for designing and repairing/updating
			New projects based on hazard/risk assessment	binary	yes/no	1			
			Level of coordination among stakeholders	degree	low/medium/high	1			
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites to wildfire	binary	yes/no	1		Municipal/ county levels	
			Retrofitting measures for existing production sites	binary	yes/no	1			
			New projects based on risk assessment	binary	yes/no	1			
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary	yes/no; expert judgement on quality	1			Enchained hazards are considered in the framework both natural (in the natural system part) and technological (here)
Social system (agents)	*People/individuals*	Capacity of individuals living in prone hazard areas of coping with hazardous events, which largely depends on the perception and awareness of risk conditions before the event occurs.	Risk perception/ awareness	Degree	strong/average/low	0,5		Municipal/ county level	
			Reliance on institutional firefighting capabilities	Degree	strong/average/low	1			
			Felt responsibility for firefighting and fire mitigation	Degree	strong/average/low	1			It is in general important to understand if the community feels shared responsibility with government and agencies in risk mitigation
			Tools and plans to guarantee early warning reach the communities	Binary	yes/no	1			Here early warning are considered in the wider perspective, considering whether or not there are the conditions for their effective communication to the potentially affected ones
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	hydrant available/not available; escaping routes known/not considered	1			
	Community and Institutions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awareness	Contingency plans for firefighting	binary	yes/no	1		Municipal/ county level	
			Effectiveness of measures included in contingency plans	degree	strong/medium/low	1			
			Participation in development and prevention/mitigation strategies	degree	strong/medium/low	0,5			
			Education programs & media campaigns	binary; frequency	yes/no; every year/only seldom	0,5		County/ regional level	
				tailored to the community features	yes/generic	1			
				Inclusion in school programs	yes/no	1			
			Economic access to resources for firefighting	degree	vewry low/low/average/high	1			
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	strong/medium/low	1			

Table 2.1.b - Matrix to assess mitigation capacity to forest fires

In the third section devoted to critical infrastructures, the main factor to be considered refers certainly to the existence and efficiency of water systems to be used in case of need; in the meantime the potential for na-tech in industries is addressed as well. In the last section, the preparedness of individuals and institutions is appraised, identifying parameters that "measure" the availability of extinguishers, masks as far as individuals are concerned, and presence of well equipped and trained volunteering firefighters. As it can be seen in the table, two columns are provided for weights and scores. The first represent the relative importance of parameters, as derived from literature and expert judgment; the second translates into a score (according to an arbitrary system that assign for example 5 to low vulnerability and 1 to high or viceversa) the evaluation carried out in the are of relevance.

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Paramters value/categories	weight	score	scale	Comments
Natural environmer	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	land cover inflammability	Surface fuels	Only needle or leaf litter on the ground; sparse low vegetation; tall dense phyrgana or shrubs	1		Those paramters clearly have to be assessed at least at a county scale	In the case of forest fires clearly the vulnerability of the natural ecosystems is crucial (type of vegetation, density, etc.)
				Existence and cover of tall tree crowns	No tree crowns; tree crown cover of <40%; tree crown cover >= 40%	0,5			
				Type of trees (see next page for details)	according to the classification provided by Dimitrakopoulos and Papaioannou, 2001	1			
Built environment	*Exposure and vulnerability of built environment*	Factors that make the urban fabric and public facilities vulnerable to the stress	Average vulnerability at the municipal scale, considering settlements(rural) or urban parts	Considering parameters provided in the attached specific table	Low-medium-high vulnerability	1		This parameter makes sense at an urban /county scale,	This table looks at a municipal/county level, while some paramters clearly make sense only at larger scales. In the meantime for assessing the vulnerability of individual buildings a more local scale must addressed (see next table)
			Historic sites (archeological) and buildings (monuments and museums) in the hazardous areas	Binary; extent and relevance	no/yes; dimension; minor/relevant/very relevant	1			
			Built pattern (follwoing Lampin-Maiillet et al., 2009)	Building density and proximity is an indicator for assessing potential sources of ignition and surface to be cleared from vegetation	very dense; dense, scattered; isolated	1		This parameter makes sense at an urban /county scale,	The quoted study showed that sparse buildings are ore likely than grouped to create multiple sources of ignition
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines)	Vulnerability assessment of critical infrastructure	water system pressure	normal/ too low pressure for hydrants	1		At a muncipal/ county scale	
				self eater tank	available/not available	1			
			roads	interaction with fuel	large road sections in open zones/in the middle of fuel areas	1		Both a the scale of the assessment and at larger scale	
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	as for buildings, but including attention to storage of hazmat	structurally vulnerable/low vulenrability; large storage/no storage	1		At a muncipal/ county scale	
			Vulnerability due to dependency on lifelines	depending on the degree of dependance upon external vulnerable lifelines	self eater tank available/not available	1		At a muncipal/ county scale	
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Sparse population	ratio between population living in isolated buildings and remote settlements and total population	r <5%; r > 20%	1		At the municipal/ county scale.	This parameter would make sense also at a regional scale analysis, but adopting statistical techniques and mapping
			Preparedness	self protection means	hydrants at home/lack of hydrants	1		At the municipal/ county scale	
				self protection against smoke	availability of masks/lack of	1			It is important in the methodology to be as specific as possible, so the generic assessment of the availability of means and personnel for mitigating the impact are tailored to the sepcific threats against which the population must be protected.
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	> 65; number of handicapped	1			
	Community and Instituions	Factors that may lead to large number of victims	Distance from firefighting resources	time of arrival	within 30 min; > 1 hour	1			
			Availability of trained personnel	professional training in the community	firefighters (professional+volunteers)/only professional	1			

Table 1.2: Extract of the matrix to assess physical vulnerability to forest fires

The next column is devoted to the spatial scale at which the parameter is evaluated. In some cases such scale has to be decided depending on the area to be covered and the context at stake. If the problem is assess the vulnerability of an entire province (as will be seen in the Ilia case in Greece, see WP5) the county or even the regional level must be taken for most parameters; if the focus restricts on one sub-area, a municipal scale can be addressed. For some parameters, like for example law and norms provision, that have clearly a relevant impact on mitigation, a national level must be taken, or regional in those states that grant legislative power to regions regarding the topic of interest (in this case protection against fires).

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters value/ categories	weight	score	scale	Comments
Natural environment	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	soil deterioration	increase of erosion	<= 30 %; 30 x x < 50%; x>= 50%	1		At the county or regional scale	
			landslide hazard	degree of increase of landslide potential based on survey and exprt judgement	low/medium/high	1			
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Existence of public facilities and resources to face the emergency	Availability of movable fire fighting equipment or of an automatic fire-fighting network (E3)	yes/no	1		At the county or regional level	
			Accessibility to vulnerable areas	Buildings density and proximity (follwoing Lampin-Maiillet et al., 2009)- total perimeter to be protected	very dense; dense, scattered; isolated	1		At the municipal/county level	Various studies attempted to assess the vulnerability of the urban fabric based on features like house density, totla perimeter to be cleared by vegetation and total surface to be protected in case of fire
				Roads characteristics	Type of roads serving the various settlements			At both muncipal and county or regional level	
					Plain roads/mountain roads				
				Signs in roads and streets (names, numbers, etc.)	yes/no			Local/municipal level	
			Accessibility to public facilities	existence of public facilities in the area	yes/no			At the county or regional scale	
				expected travel time	t > 30 min/ t <= 30 min				
				road network to public facilities	as for accessibility to vulnerale areas				
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Existance of lifelines	Availability of water for firefighting	Yes/no; in sufficient number/insufficient	1		At the muncipal and county level	
					Existence of a swimming pool or a water tank of more than 3 m3 in the plot	0,5			
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	water for fighting	existence of tanks and devices for firefighting			At the muncipal, county and regional level depending on the focus of the assessment	
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time	as for roads network to vulnerable areas				
			Contingency plan for na-tech	binary	yes/no				
			Business continuity plan	binary	yes/no				
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	Trust in information provisers	binary	yes/no	1		Clearly this can be assessed only at regional scale	Apart in some very special context where the local perception and situation is different from the regional/national
			Tenants, landowners and neighbours have been trained in fire-fighting	binary and frequency of training	yes/no; every x months/only occasionally	1		At a muncipal or county scale	
			Voluntary fire fighers	binary; number	yes/no; number /neighborhood	1			
			If previous yes, then Training	degree of training and means availability to volunteers	good/average/low	1			
			Presence of impaired groups (elderly, sick persons, etc.)	binary; number and accessibility to leaving areas	yes/no; numbr/neighborhood and accessibility	1			
	Community and Instituions	Factors that may hamper effective crisis management	Existance of contingency plan fro threats at stake	binary; date of last production or update	yes/no; recent/>2 years with no updating	1		At acounty or regional scale	
			If previous yes, Training using the contingency plan	binary; frequency of training	yes/no; every year/only occasionally	1			
	Economic stakeholders	Economic stakeholders preparedness to face crises	Capacity to run economy and respond to crises	degree	yes/partially/no	1		At a county or regional scale	
			Capacity to invest in recovery and take preventive actions	Binary or degree	Yes/no or none/partial/high	1			

Table 2.3: Extract of the matrix to assess systemic vulnerability to forest fires

The mitigation table for forest fires has been provided integral, comprising all parameters that have been selected; in the next tables, only an extract of the tables will be provided to facilitate readability of the individual parameters and comments.

Regarding the physical vulnerability (table 2.2), the main aspects that have to be considered are clearly:

– Inflammability of vegetation, buildings and infrastructures. In this regard some studies highlighted that the pattern of the urban fabric is important to determine ignition points and frequency. For example Lampin Maillet et al. (2008) show that sparse and isolated buildings pattern produces more ignition points than dense pattern, based on their studies of fires in Southern France;
– As for the built environment, important is also adherence to rules of construction and maintenance of open spaces that reduce flammability and avoid fast development of fires;
– As for critical infrastructures, the conditions of roads, their interaction with flammable areas (crossing forests for example) are fundamental parameters to be accounted for;
– Addressing social and individual preparedness, self protection means and adequate behavior (which requires prior preparedness) determine to a significant extent survival rates, particularly in extremely severe fires.

As for systemic vulnerability (see table 2.3), all factors that may worsen the response to emergency are considered, as the possibility of soil erosion and landslides as secondary effects of slopes denudation. Furthermore, conditions that favor or constrain successful firefighting are considered. Therefore accessibility factors within and towards potentially stricken areas become crucial elements to evaluate how fast and effectively it will be possible to evacuate on the one hand and for firefighting and rescue teams to arrive to the burnt zones. In this case the same parameter considered in the physical vulnerability table, buildings density and proximity is used to determine what will be the total perimeter to be protected by firefighters. Clearly it is both easier to reach and to protect dense built block with respect to a large number of isolated buildings sparse over large areas.

Finally regarding resilience (table 2.4), the capacity of the natural environment to "bounce back" has an ecological meaning: some species may recover faster than others, the extent to which plants have been damaged condition post fire recovery. In literature it is hold that also post fire management (for example types of plants selected for re-vegetation and availability of maps and pictures to document pre-fire situation) are crucial to determine what will occur in the affected area. The resilience of the natural environment has repercussion also on economic sectors like tourism and agriculture, for which the integrity of landscape is an essential condition for production.

What has to be taken into account in both the post and the pre-event phases is that to a certain extent successful fire prevention practices may lead to more severe and devastating extreme fires once the latter finally occur. In this regard, parameters attempt to capture the need for judicious practices that acknowledge the fact that fires are natural events and are part of the ecosystem of forests and woods.

As for other natural hazards, the "hazard" is part of the natural functioning of the environment, while it becomes a disaster when vulnerable communities and settlements are exposed.

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Paramters values/ categories	weight	score	scale	Comments
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from damages	Fire recovery	Post fire vegetation re-growth	South facing slopes/North facing slopes	0,5		At a municipal/ county level	A post vegetation fire study took place in Mount Carmel, Israel. Unlike the study from Delgado, the recovery of vegetation was seen to occur better in north face slopes in contrast with south facing slopes. This seems to be a dominant assumption on the fire comunity. The choice for 4 and 2 vulnerability scores reflect that the difference is not very extreme, as highlithed by the study.
				plants used for reforestation	use of endemic species for reforestation/use of fast growing vegetation	1			This parameter is very country specific. In theory salvage harvesting can indeed lead to decreased regeneration after a fire, but harvesting can also lead to lower fuel loads at the stand and therefore make the fire less intense... It is a tricky issue. Maybe one can focus instead on post burnt fire policies. How is the reforestation of burnd areas planned? do they use endemic species or do they relly on fast growing vegetation (in general less resiliant and more prone to fires)?
		Structural and non structural recovery measures	availability of maps and pictures to document regeneration	binary	yes/no	0,5			Usually studies make use of satellite pictures to document changes in post-fire vegetation.
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Existance of plans and provisions to encourage mitigation in buildings and surrounding zones	binary	yes/no	1		National/ regional level	Difficulties in vegetation clearance around buildings due to ownership obstacles
			Level of integration of physical reconstruction with community healing processes	Room is given for interpreting in the new/restored setting the meaning of the destruction (After Valen and Campanella, 2005)	High/low	0,5		muncipal/ county level	
			Existence and strength of norms prohibiting building in burnt areas	binary; degree of compliance/inspection capability	yes/no; low/high			national/ regional level	This is clearly a crucial resilience factor, very specific to forest fires that are many times man made with the objective to create conditions for urbanisation
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Water system for firefighting	level of improvement after disaster	low/high	1		Municipal/ county level	
			In site devices for quick survey of damaged parts	binary	yes/no	1			
			Availability of spare materials for fast repairs	binary	yes/no	1			
			Availability of personnel for repairs	binary	yes/no	1			
			Existence of protocols to proceed with repairs requiring inter-lifelines interventions	binary	yes/no	0,5		county/ regional level	
	Economic activities	Availability of tools to recover production sites rapidly and at low costs	Relevance of the area as a tourist attraction	degree	low/average/high	1		municipal/ county level	Clearly in the case of forest fires the burnt areas constituted a unique landscape that until recovered will not be available for activities strongly dependent on it
			Activities depending on the existence of woods	binary	yes/no	0,5			
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	1			
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of private resources for recovery	degree	yes/no			Municipal/ county level	
			Access to insurance	binary; coverage	yes/no; percentage of coverage				
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Aging population; low fertility rates	indexes				Those parameters as well as others that are not reported in this sample are aimed at assessing the strenght, cohesion and recovery capability of the local comunity affected by fires
			Local condition of aged population	autonomous/not autonomous; relatively healthy/not healthy	autonomous/not autonomous; relatively healthy/not healthy				
			Employment rate	degree	high/medium/low				
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Trust in institution	degree	high/medium/low (from sociological surveys when available)				
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no			regional /national level	
			Long term vision	Existance of strategic development/land use plans	yes/no			regional/ county level	It is deemed very important to have a long term vision to strenghten resilience, that will consider the development in a longer time horizon, including the possibility of further hazard impacts
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	binary; coverage	Yes/no;percentage			municipal/ county/regional level	
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricultural activity	percentage				

Table 2.4: Extract of the matrix to assess resilience in areas exposed to forest fires

Considering the resilience of communities and population, an important aspect to be considered in reconstruction after a devastating event like a fire, which causes in many cases the total loss of people's belonging and memorabilia, is the cohesion of society, the capacity to develop a long term vision and the positive conditions for permitting healing of trauma and not just physical rehabilitation.

3 Critical discussion of the integrated framework (largely based on first application to the test case study areas)

The application of the framework to the test case study areas (see WP5) provided a crucial return in terms of acquired experience and highlighted both strengths and weaknesses of the methodology.

The framework is at a stage of a prototype; some difficulties in applying it to concrete cases derive from this inherent character. On the other end, the experiences gained in applying the framework evidenced some points that could be hardly raised based on theoretical perspectives only. The most relevant relates to the need to include the framework into a larger assessment procedure, where the fulfillment of the matrices is still the most relevant part, but not the exclusive one.

In other terms, one must consider the evolution (both in time and ??? as far as research efforts must be taken into account) of the framework and the related matrices. First a general scheme has been produced, in the attempt to capture the most relevant components, features, issues raised in the discussion about vulnerability and resilience. Second, the general scheme was specified, producing matrices in which parameters and criteria to appraise vulnerability and resilience were tailored to distinct hazards.

Indicators received a specific connotation, showing what were the main features and aspects making a given environment (natural/built/social) more or less prone to damage and more or less capable to mitigate and/or recover. Such tailoring entailed a choice which is somehow questionable, as reference to individual hazards is explicitly made while the ambition to be general/comprehensive/multirisk is temporarily abandoned in favor of a more traditional kind of approach. The pro of such choice though, has been the potential of exploring vulnerability and resilience across several cases, defining in a much more precise and concrete manner what makes a given environment more or less fragile.

Still, even with this level of specification, matrices remain at a "general" level, somehow independent from specific contexts. And here the issue of how to adapt the assessment to the understanding of the context pops out in a very relevant fashion. Application to test case study areas evidenced that a clear cut straightforward application of the methodology, and in particular of the framework and the matrices, is not possible. One may even say that this could have been expected since the beginning and that actually an obvious process of tailoring and adaptation, this time to the context at stake, had necessarily to be forecasted. In any case, testing showed in a very evident way this need. Therefore a clarification of how to use the framework, even at an experimental stage, before moving from the prototype towards a more ready-to-use tool has to be provided (see paragraphs 3.2 and 3.3).

3.1 Quantitative or qualitative vulnerability and resilience assessments: a misplaced question

As stated at the beginning of this paper, and as explicitly stated since the beginning of the Ensure project proposal, one of the main needs felt by the partners was to integrate both "hard" and "social" sciences issues to assess vulnerability and resilience.

"Hard" sciences provide information and insight to understand why given infrastructures and structures fail under given stress, be it the physical stress of the natural agent or the malfunctioning provoked by a certain level of physical damage to critical systems or components. Social sciences in their turn provide explanations and example showing how and why given communities are better equipped than others to face natural calamities. This has to do with the physical and functional consistency of assets, but also, in a meaningful portion, to less "tangible" facts, entailing social cohesion, robustness of economy, cultural and human resources. The Ensure project started its own research path from the recognition that mitigation policies must take into account the "two" sides of the coin. (A coin is certainly a simplification, as we should talk about a multifaceted prism, yet it can be accepted for the purpose of the following discussion).

Conditions for better overcoming a crisis, a calamity depend on several circumstances and conditions that partially have to do with material components and partially with social, institutional and economic arrangements. Not to mention the fact that the "hard" and the "soft" sides are not separated, they continually interact and such interaction produces fragilities and strengths. Therefore, any attempt to assess the response capacity to an extreme event, must consider both sides of the coin and possibly their mutual interconnection.

At the end, as stated by Winograd (n.d.), the goal of vulnerability assessments should be «turning the data into relevant information and information into action».

Be it in the form of a list of factors to be considered or in more complicated schemes, as the one proposed in Ensure, an agreement has to be reached (even a temporary one) between – to simplify- social and "hard" scientists/engineers.

The very first level is mutual respect and recognition of importance of matters which are studied by the other discipline; the second step is to face the objective difficulties and obstacles in making the coexistence of two different mindsets and models of thinking and analyzing.

In this respect, in the vast literature devoted to this certainly not new issue, a particularly insightful perspective is offered by Ginzburg in an article written in "History Workshop" in 1980. In the article, he discusses the main obstacles to mutual understanding and recognition, referring to the irreducible difficulties whenever the "human" component has to be considered, something which sounds certainly familiar to most "hard" scientists working in the field of risk.

Whilst a couple of decades of interdisciplinary research have set the floor for a different attitude with respect to the past, and as more mature positions have emerged recently, overcoming complete lack of communication and disciplinary barriers, there are still key issues that require further reflection and settling of divergent positions. This is deemed to be relevant not only to improve communication and knowledge exchange between "social" and "hard" scientists to limit the discussion to the "big" categories (whereas we are perfectly conscious that large gaps exist also within each "block") but also to answer a key question for the project: are vulnerability and resilience assessment "science"? And, as a next question, going after a similar one posed by scholars in sustainability "science" (Bell and Morse, 2008): are vulnerability and resilience assessment "good" or "bad" science or even "bad transposition of otherwise good science"?

Ginzburg suggests that there are two main irreducible differences between what he calls Galilean and social sciences: on the one hand the treatment of the individual as opposed to the typical and therefore treatable in statistical (quantitative) terms and the capacity to predict the behavior of a variable, the evolution of a given phenomena.

As for the first point, clearly social sciences cannot avoid studying the individual, without losing critical information and understanding; attempts made by some social scientists to get closer to hard sciences resulted in rather "meager" results according to Ginzburg. In the meantime the author asks whether or not we can get to a situation where the understanding of the individual is somehow "scientific", if conjectures that characterize "soft" sciences can be as rigorous as quantitative modeling. Without entering into the much wider debate of the so called "post normal science", in which for example Funtowicz and Ravetz (1990) demonstrated that even "hard" sciences have undergone a significant mutation that has brought them quite far from the Galilean model, the point made by Ginzburg is still relevant. He points at the divergent mindsets, according to which "hard" and social scientists judge method and rigor, which still constitute a formidable obstacle to working together.

In the case of vulnerability and resilience studies, we may even go further and state that the point is not just making the two fields communicate, but actually develop possibly good science at the border of the two fields (and the many more disciplines within each) to address issues that are in the meantime material, physical and human, social. Continuing referring to Ginzburg's article, resilience and vulnerability assessments resemble to a "medicine" type of effort, where classifications of diseases (in our case classes/categories of vulnerability) and the symptoms to be considered (the indicators) and how to judge their relevance and severity (criteria for assessment) are at stake. Within the framework, some indicators respond more to a Galilean type of science, when statistical methods and sufficient data can be used for their assessment (typically most of physical vulnerability parameters and some systemic in the sense adopted by the project). Many others (typically all those referring to social systems) will remain at a "classificatory level". The point is therefore whether or not the two types of assessments can or even should coexist in the same framework. We think that even though in a rather imperfect way, the framework provides an acceptable level of integrated vision of the different aspects that must be taken into account in vulnerability and resilience assessments, without sacrificing relevant fields where knowledge on response of social, built and natural environments to extremes has been produced.

We are of course aware of some inevitable limitations such an endeavor implied since the beginning.

First, it is clear that the different indicators and parameters do not simply address different issues, but actually manifest also different ways of capturing vulnerability. Their co-existence in the framework is somehow arbitrary, as they actually play at different levels, not only in spatial and temporal scales, but also conceptually.

Nevertheless, given this minus, the framework offers a synoptic vision of what current literature and experiences have produced insofar, posing in a transparent way and in open access terms the question of how different views can/cannot coexist to provide a more articulated and nuanced picture of a system or a territory at risk.

Second, it is as well recognized that the tool that has been developed is currently a prototype and should be managed as such. It cannot be simply given to potentially interested stakeholders leaving them "alone" in the application of the framework and associated matrices.

As the application to the test case study areas evidenced, a number of intermediate steps must be followed in order to use it at best and none of them can be at the moment "standardized". Some of those preliminary steps as described in paragraph 3.2 can be considered part of a more general and thorough procedure, where the use of the framework is certainly a core component but not the exclusive one. On the other hand, tuning and adaptation to the specific context at stake have to be made because of the prototype character of the framework and the related matrices. Therefore, in a further evolution of the methodology, a sort of discussion and participatory approach should be taken, involving different stakeholders to understand with them for what specific purposes, how, to what extent, and with which changes the methodology can be successfully applied.

Apparently, considerations made by the various teams working on the test case study areas showed that the methodology, and the framework which constitutes its skeleton, are valid in that they set the floor for a comprehensive evaluation, considering multiple dimensions and facets of vulnerability and resilience. Difficulties arise in the assessment of some parameters, because of the way they have been conceived and constructed. Further research in this domain could enhance the applicability of parameters (see in this regard also paragraph 3.3 and section 4). On the other side, getting acquainted with the methodology requires some time and practice. Guidelines to help follow the methodology may certainly help, but as stated by Ginzburg «in medicine, history/human sciences (and we may add in vulnerability and resilience assessments), the elastic rigor – to use a contradictory phrase – of the conjectural paradigm seems impossible to eliminate. Nobody learns how to be a diagnostician simply applying rules».

This leads us to the second important difference between "hard" and "soft" sciences as discussed by Ginzburg: that is the prediction capacity (or lack of). Because of the relevance of the individual in social and human affairs, only a retrospective prediction can be attempted. The "conjectural" paradigm of history or criminology may reconstruct a posteriori an event or the scene of a crime. Much more difficult and even questionable is the possibility of "prospective" prediction, to forecast how the future will unfold, how and if a crime will be committed.

Whilst clearly even in "hard" sciences the capacity to predict is not that obvious and banal, particularly when large uncertainties are implied (see Sarewitz et al, 2000), still the evolution of variables with constant characteristics can be reasonably forecasted. As for disasters, the debate between those who held that each event is unique and those who privilege constant and repeated behaviors and patterns is still very harsh. Again the metaphor of medicine can be useful for vulnerability and resilience assessments: indicators can be treated as "symptoms" of a condition the quality of which can be fully grasped only within a scenario type of exercise. Whilst the development of damage scenarios was beyond the application set for the Ensure project, it became clear through the test case studies that only conditioning certain indicators to a predetermined scenario it was possible to fully appraise them, particularly when cross scale relationships were crucial.

3.2 Temporal and spatial scales: a viewpoint from the Ensure project

The issue of scale has been rather neglected or poorly appreciated for a rather long extent, while in the meantime the concept of vulnerability, coping capacity, resilience and related concepts were undergoing a significant evolution process. It has become the centre of interest and studies with the first applications of climate change scenarios, particularly when the latter had to be regionalized, and with the development of the first global integrated assessments of the state of the environment and risks. The main question that the latter analyses have raised regards the relevance for local places but even for regions of projections and scenarios that have been drawn considering global trends and processes, while neglecting the information that can be gathered locally. It was clear for the scientists in climate change and those involved in global environmental assessments that for some phenomena, what happens in a given place, or at a micro level cannot be always neglected, as sometime it may contribute to change the evolution or patterns at much larger scales. Therefore a reflection on the meaning and use of scale in such studies and conversely in natural hazards has broken through various research groups, producing insightful thoughts that are relevant also for the Ensure project.

The reason why the scale issue is crucial can be derived from the rather enlightening and systematic discussion by Willbanks and Kates (1999):

- For the "tractability" of the problem at stake: when considering for example the vulnerability of buildings, a one by one survey can be carried out in very small municipalities and in any case only locally; when the vulnerability of entire provinces, counties or regions must be appraised, sampling techniques or even statistical analysis based on poor data (like census data) has necessarily to be adopted. This does not mean that studies at larger scales are less reliable: they obviously serve another purpose, which is the setting of strategies and policies identifying priorities, rather than deciding about individual interventions. Many other examples can be presented; in general it is true that vulnerability assessments regarding several components of vulnerability are much more tractable at the local scale, and the quality of information that can be gathered is much higher. Nevertheless, the limitations of investigations conducted only at the local level should be pointed out as well. First, the resources necessary to carry out a thorough survey are limited and therefore many localities will not be covered because of lack of time, money, personnel; second, at the local scale some relevant factors influencing trends and conditions can be missed, as they operate at other scales or levels. It is rather hard, perhaps impossible, to identify the "right" scale or level at which to analyze a given problem, as the latter depend on the purpose of the assessment, on the available resources but also, importantly, on the type of patterns and phenomena that have to be investigated. This leads us to the next point.

- A multi-scale, multi-level approach is relevant whenever "emergent" aspects, patterns, relations emerge at higher (or lower) scales and levels and therefore missing them may invalidate the entire assessment. An example is provided by lifelines vulnerability assessment: because of their intrinsic hierarchical structure and of their mutual interdependence, studies conducted at a local level may completely miss the relevant interconnections that are both spatial and systemic. Furthermore not just one level is implicated in infrastructures organization: actually it depends on the specific arrangements in a given country or even continent. Before moving to the analysis of the local vulnerability of lifelines, one must estimate where the vital links, nodes, segments are. In this respect, it may be suggested that physical vulnerability assessment is more likely to be "local", whilst "systemic" vulnerability as defined in the Ensure project is more likely to be grasped at higher levels, regional or national. Following Root and Schneider (1995) a "cyclical scaling" method has to be preferred to rigidly pre-defined "top-down" or "bottom-up" approaches, going from the local to the regional or national and back to the local, depending on the question to be answered with the vulnerability and resilience assessment.
- Considering multiple scales and levels supports even more strongly the need for a methodological strong framework as the one suggested by the Ensure project. In fact, a definite rule valid for all types of assessments cannot be established, as the choice depends on the objective of the assessment but also on the systems to be analyzed and on the specific context where the analysis is carried out. Such a framework, by establishing how given parameters and topics must be addressed at what level and scale, is better fit than case by case analyses to accomplish what Willbanks and Kates (1999) see as key requirements: put localized observations into a reference context; increase the comparability of studies conducted at the same spatial level and across time. This is a requirement that has been stated, even though phrased in other ways, by the Asean group producing the Post Nargis Cyclone assessment of needs and damage in the affected Myanmar areas (2010). The latter shares with Ensure a similar philosophy, according to which vulnerability and resilience evaluations are useful exercises only at the condition that they support and offer insight for deciding mitigation and prevention strategies.

It must be acknowledged that introducing scale into vulnerability and resilience assessments is not easy; there are not available standards or references that can be taken as a guidance. But even in more general, theoretical terms «improving the understanding of linkages between macroscale and microscale is one of the great overarching intellectual challenges of our age in a wide range of sciences» (Willbanks and Kates, 1999). The authors continue suggesting that «weaknesses in appreciating the interaction of processes moving at different time scales and extents, in fact, underlay a great deal of the current scientific interest in complexity, non linear dynamics, and the search for order amid seeming chaos». The issue of scale is particularly important when different scientific perspectives must cooperate together in a truly interdisciplinary way. As suggested by Root and Schneider (1995) «the scale at which different research disciplines operate make multidisciplinary connection difficult and necessitate devising methods for bridging scale gaps». Having said that, it is clear that what can be realistically achieved within the Ensure project is first an explicit recognition of the importance to consider the scale issue as a central one and second a proposal of how it can be operationalized within the proposed methodology.

In accordance with the already quoted definition of vulnerability provided by Turner et al (2003), we may well take the definition of scale as suggested by Gibson et al (2000): «We use the term scale to refer to the spatial, temporal, quantitative or analytical dimensions used by scientists to measure and study the objects and processes. Levels on the other hand refer to locations along a scale».

In the suggested framework, both the spatial and the temporal scales of disasters are considered to structure the analysis of vulnerability and resilience. It is also suggested that even though both concepts are dynamic and dynamism is a crucial aspect to understand how and why given levels of vulnerability or resilience can be "measured" today, what can be practically achieved is a "picture" of frames at meaningful levels of the scale.

In order to operationalize the concept of scale, then two main aspects will be discussed in the following paragraphs: first what are the relevant levels for each scale to investigate for what purpose; second how we may treat cross-level and cross-scale relationships.

Following what has been discussed until now, the following can be proposed for the Ensure project in practical terms:

a. Scale up and down, adopting statistical and sampling techniques for those aspects (particularly physical vulnerability) that are cumulative (which means that the physical vulnerability of buildings in a region can be seen as the additional vulnerability of every single building);
b. For systemic vulnerability, a cycling scaling approach may be adopted, going up to the largest spatial scale necessary to identify functionality at the lower (or local) level of concern;

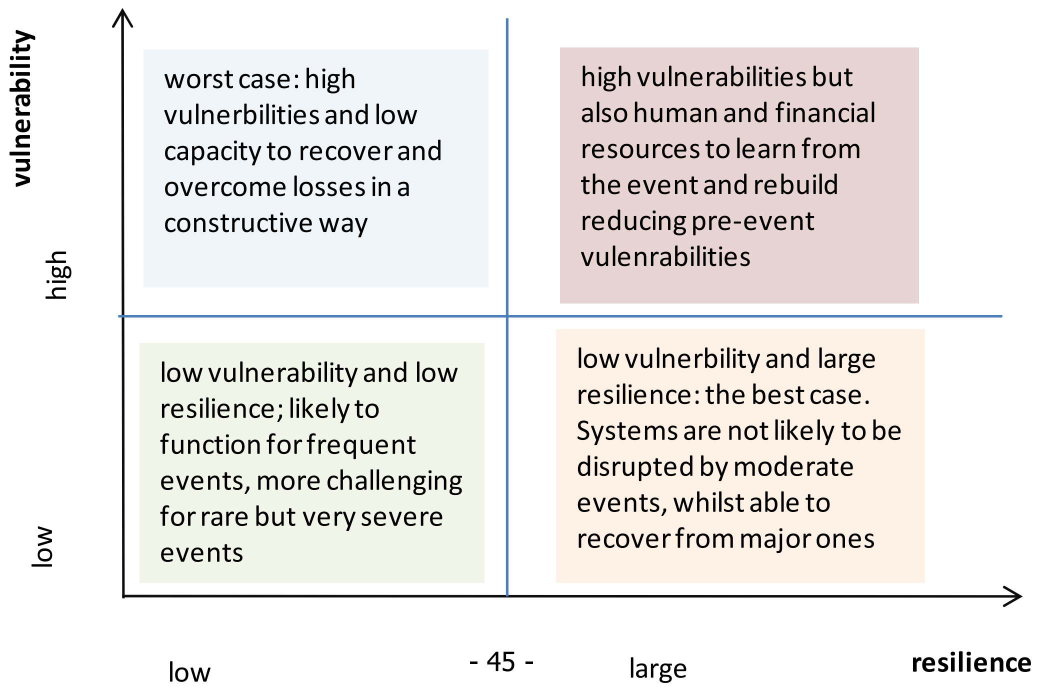

Figure 3.2: Scheme to sketch the cross temporal scale relationship in a given area and context

c. For mitigation and resilience, the appropriate spatial scale depends very significantly on the purpose and the end user of the assessment. In this case, a "mapping" approach following the one proposed by Briguglio et al (2008, see figure 3.2) can be followed. In other words, one has to first identify in the case at stake what are the agents and the economic stakeholders that are most relevant for understanding a given pattern of preparedness (or lack of) and of capacity (or lack of) to influence physical and systemic vulnerability and then direct the efforts into the assessment of the elements at different spatial levels that are relevant for the case at stake. For example, while talking about the physical seismic vulnerability of buildings in a given region in Italy, it may be relevant to search at the national level when laws providing economic incentives for retrofitting have been passed and what are the authorities in charge of controlling the correct use of those incentives. Then the appropriate level at which to analyze agents' behavior in this specific case can be decided.

3.3 Dealing with cross-level and cross-scale relationships

Insofar the framework description has provided a static picture of the vulnerability assessment, providing the explanation of what can be viewed as a skeleton comprised by subcomponents and indicators to enlighten and evidence that the various factors that have been recognized in literature and past applications as relevant for understanding the potential response of a complex territorial system to the "external" stress due to a natural extreme.

The Ensure team though has acknowledged since the first WPs (in particular the second one) that links, connections, coupling relations exist among indicators. More than that: the validity of a vulnerability assessment requires the understanding of such connections to avoid misleading results that do not take into account how the various factors interact in a real setting.

Given that, the issue of how to play on the relationships that have been sometimes grasped in back analysis within the framework has still to be fully understood.

At least three types of relations can be recognised.

The first (see figure 3.1) relates to how the different indicators within the same matrix may be connected to each other. In general term, it can be assumed that social agents in various forms may have a direct or indirect, strong or loose influence on all other types of vulnerability, that is on the vulnerability of natural systems (for example the decision to change the type of vegetation coverage for economic profitability may induce instability in slopes or give room for more inflammable species), on the vulnerability of the built environment (here the all issue of compliance with norms and state of the art techniques enters), on the vulnerability of critical infrastructures (not only the way they are constructed, but also to what extent they are privatized, whether or not managing companies are controlled, coordinated by public bodies, etc.).

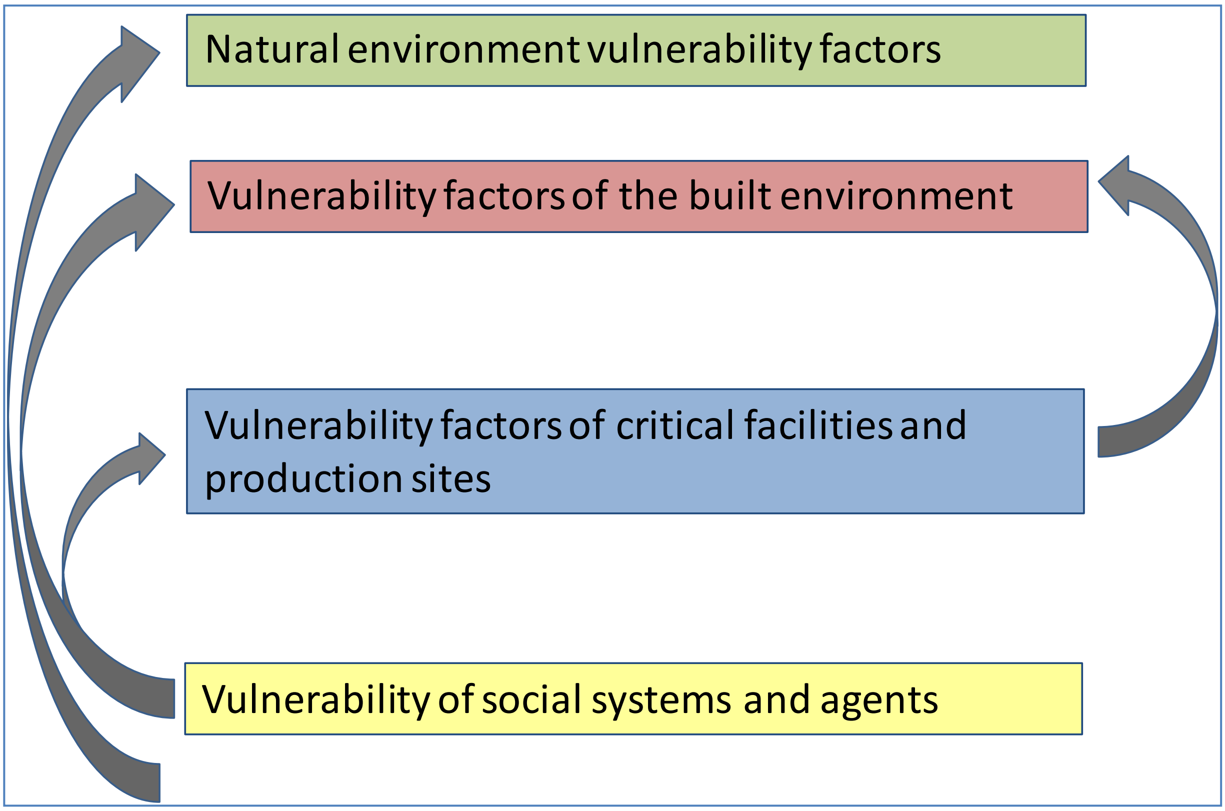

Figure 3.1: Relations among indicators within the same matrix

The second and the thirds relate to spatial and temporal cross-scale and cross level connections.

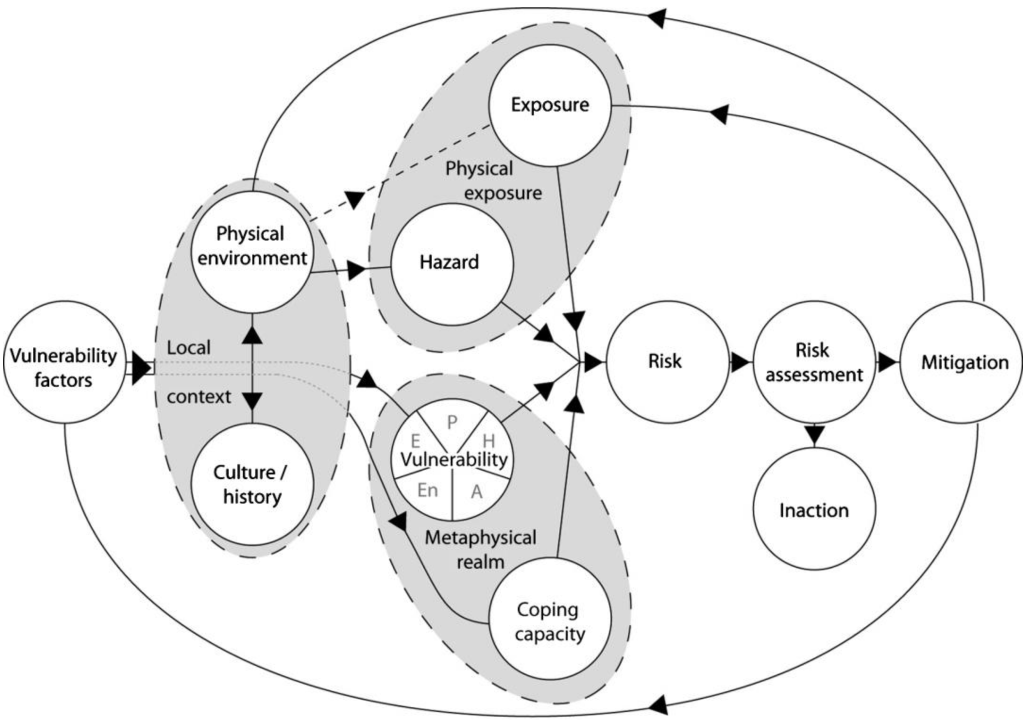

Figure 3.3: Proposed model for vulnerability conceptualization within risk assessment context by Roberts et al (2009)

As it is already very complex as shown in the previous paragraph to address scale issues per se, it is even more challenging to tackle such cross-scale relationships. As already said, whilst the relevance of such connections has been recognised theoretically, it is still rather difficult to achieve it in real applications. Having a conceptual framework is already a good advancement as suggested by Roberts et al (2009, see figure 3.3). Actually, their framework has a lot in common with ours, and can be suggested as a visualization of the kind of pre-vulnerability assessment that must be carried out in order to identify what are the relevant links among indicators at different spatial and temporal scale for a specific case at stake.

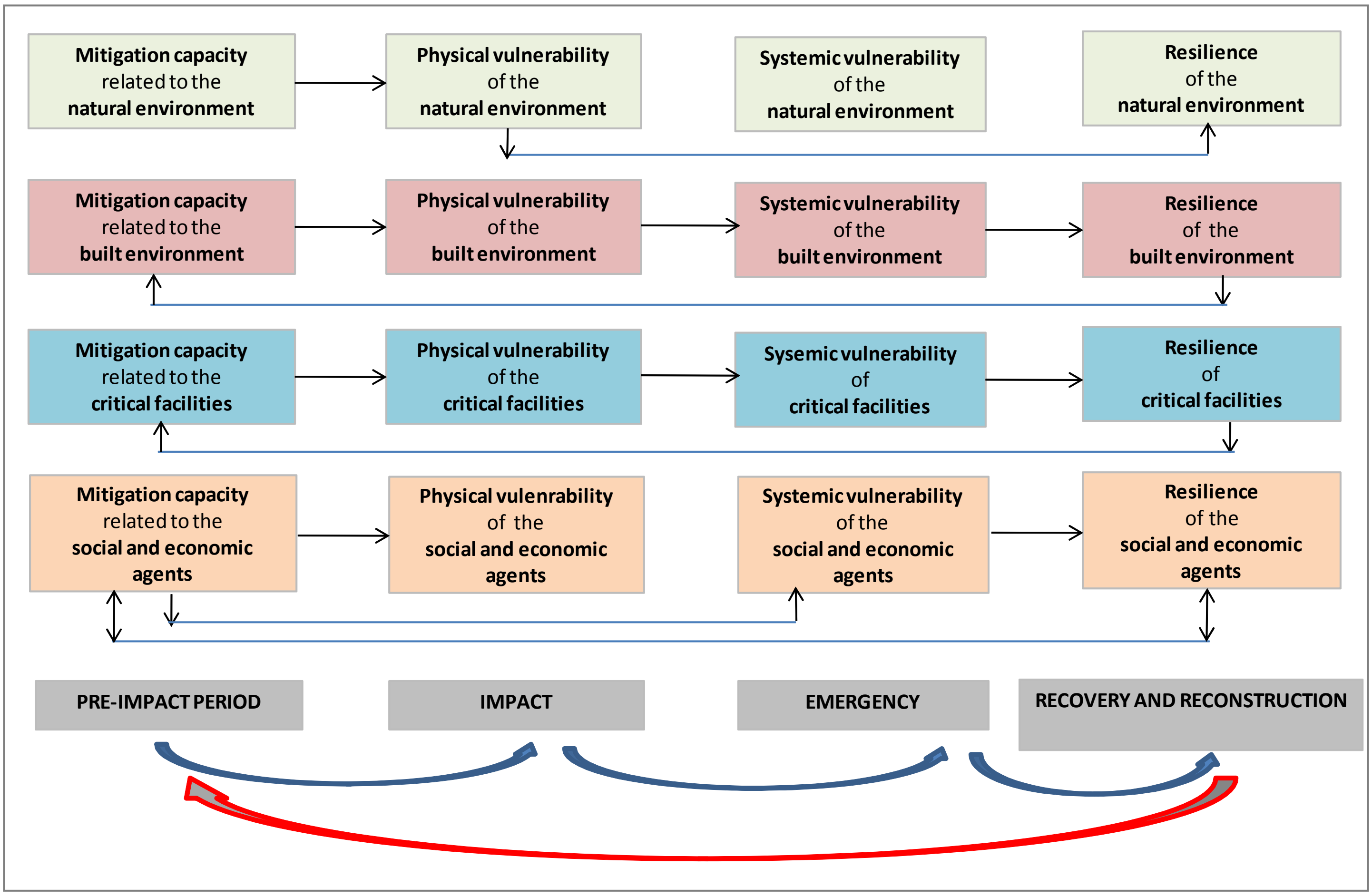

Figure 3.4: Relations among indicators across the set of matrices (referred to time-scale levels)

Again, it is deemed that a general theoretical statement of how those connections work is impossible at the state of the art (or perhaps even counterproductive form a conceptual viewpoint); instead, what can be practiced is the definition of a "scenario" where conditional relations among indicators are recognised as relevant and therefore for those indicators at the appropriate level of spatial scale the full assessment will be completed. The others will be as if "turned off" and not examined in that particular case.

Similarly for time scale (see figure 3.4); whilst it can be hold in general that what is decided in the period before the impact, the capacity or incapacity to mitigate have direct consequences on physical vulnerability, and on the systemic. The resilience of the system is not dependant only on pre-event decision, as emerging positive capacities may arise from society and territories in sometimes unexpected ways, difficult to fully envisage before the event. In this regard, while recovery and reconstruction clearly pave the floor for creating or eliminating vulnerabilities and are therefore always part of "mitigation" to the next, future, extreme event, the relation between mitigation and resilience is not necessarily so linear. Resilience, though, has to do with the expected level of damage, the extent to which places and communities are disrupted in the aftermath of the event.

In figure 3.4. the mitigation capacity, physical, systemic vulnerability and resilience of the four main systems that have been represented in the matrices are shown across the temporal phases of a disastrous event. The long arrows below the phases labels indicate that there is no linearity and that the pre-impact event sort of starts when the reconstruction is over (or, better, when enough time since the last event has passed so that the pre-impact event is felt as a "normal" time). The other arrows among the various systems' vulnerability and resilience boxes show the relations that exist inevitably over time among mitigation, physical vulnerability, vulnerability to losses, resilience. The links among systems shown in figure 3.1. should be ideally superimposed so as to represent the complexity of such cross temporal scale relationships. In the figure only some of the links are evidenced, while it is clear that many other may be found in real cases.

In summary, it is clear that as it is already very challenging to account for cross-level and scale relations as well as for interactions among indicators in back analysis, in prospective assessments this becomes an unachievable goal, if prescribed in too strict terms. It is inevitable to simplify and propose a more pragmatic approach, that will first make explicit what kind of interactions among stress → physical damage → systemic vulnerability → response to losses → assumed capacity to recover can be envisaged in a given place, in a given region at the time when the assessment has to be conducted, and then identify the most relevant relations among what indicators at which spatial or temporal level.

Even though the proposed solution is partial and not fully satisfactory, it must be reminded though that it is in line with some current proposals that have been strongly supported by some end users. An example is provided by the already quoted Asean post Nargis assessment, where a very similar approach to the practical one we propose here was adopted, under extreme circumstances under the urgency to provide quick results for the affected communities. In fact, first a spatial grid was established to identify the key levels at which the assessment would be carried out; then an indicators' framework was set to guarantee both comparability and emergence of specific needs and problems in different localities; third, the assessment looked ahead at recovery, providing a tool that could be used also across time to verify the efficacy of aid and intervention policies.

3.4 How temporal and spatial cross scale relationships can be analysed in practice within the Ensure approach: an example applied to the forest fires case.

Regional patterns of forest fires depend on numerous human, landscape and climatic factors that change frequently in time and space (Cueva 2006). For example, forest vegetation type and structure, biomass of live and dead surface fuels, land topography, weather factors, population density. Countries in the Mediterranean region of Europe are frequently subjected to the economic, ecologic and human consequences of forest fires (Bassi et al. 2008). Here a dynamic adaptation of the Ensure framework is proposed, to account for the very relevant linkages between actors and objects, across spatial and temporal scales. Although in theory the concept vulnerability demands for a thorough investigation of biophysical, cognitive and social dimensions of human-environment interactions (Polsky et al., 2006), in order to make the assessment of vulnerability meaningful an intermediate level of complexity needs to be found. In this light, wildland-urban-interface (WUI) emerges as an adequate focal system. WUIs are defined as areas where urban lands meet and interact with rural lands (Lein and Stump, 2009). Some of WUIs are characterized by increased human activities and land use conversion (Lampin-Maillet et al. 2009). In general, as people and wildland interact, the potential for forest fires becomes elevated and risks to fire hazard rise.

The suggested model depicts agents, objects and their interactions contributing to physical and economic vulnerability of the WUI's. Agents and objects are positioned according to a time and spatial axis (see Figure 3.5). The time axis denotes the traditional stages of the disaster cycle (from pre-disaster to recovery) while the space axis highlights the scales of influence for each agent and object (from macro to micro). For explanatory reasons let us focus on the pre-event stage. At this level, agents and objects influencing fire ignition and/or fire propagation are investigated, e.g. flammability and fuel structure, human activities or climate patterns (Chuvieco and Salas 1996). After *agents* and *objects* are placed in the appropriate spatial scale of influence, their interactions (represented by arrows 1 to 13) are elaborated from forest fire literature. For example, a demographic decrease in the rural areas of Portugal has lead to the abandonment of arable areas and their subsequent conversion to woodland. The resulting increase on fuel loads made these regions more susceptible to the occurrence of fires (Pereira et al., 2005). The phenomenon of land abandonment driving fires was also reported in Greece. As forests and villages were gradually abandoned, the number of forest fires and area burned annually started growing steeply since the end of the 1970s (Xanthopoulos, 2004). This relation can be abstracted by the *agent* population modifying the *object* land use and flammability (see arrow 6).

In a similar way, the agent *governance* (usually present at macro- and meso-scales of the pre-event phase) was found to shape physical vulnerability at the micro-scale via the agent *population* and their interaction with the objects *built* and *natural environment*. It was observed that residential risk management decisions (arrows 7 and 8) are made in reference to institutional incentive provided by the existence of public fire suppression (arrow 3). If residents believe that fire-fighters have the capacities to protect local homes they are less likely to implement measures to reduce home ignitability (Collins 2005).

Resulting physical vulnerability during the impact phase translates to economic consequences on the course of the recovery phase. Examples from the 2007 Greek mega-fires showed that around 78000 ha of agricultural land burned on Peloponnese were primarily olive groves. In the Prefecture of Ilia alone 50% of the olive production potential was lost, such damage should be seen in relation to the main source of income in this area (WWF 2007). Access to insurance by the agents *economic stakeholders* (arrow 11) or the existence of governance funds to cope with disasters provided by governance (e.g. European solidarity fund, see arrow 12) have a positive effect in reducing economic vulnerability at the micro-scale. The agent *economic stakeholder* revealed to play a double role in influencing economic and physical vulnerability. While its effect is positive at the recovery phase, the continuous maintenance of insurance structures might, in the long run, have a negative effect on physical vulnerability at the micro-scale. Using focus group methods Winter (2003) found evidences of a substitution effect in which residents believed "their responsibilities relative to wildfire risk are fully discharged by maintaining insurance coverage on their home" (arrow 13). This might result in difficulties in changing the spatial arrangement of settlement patterns (built environment) that is in turn linked with ignition sources in the natural environment (Cardille et al., 2001; Syphard et al., 2007).

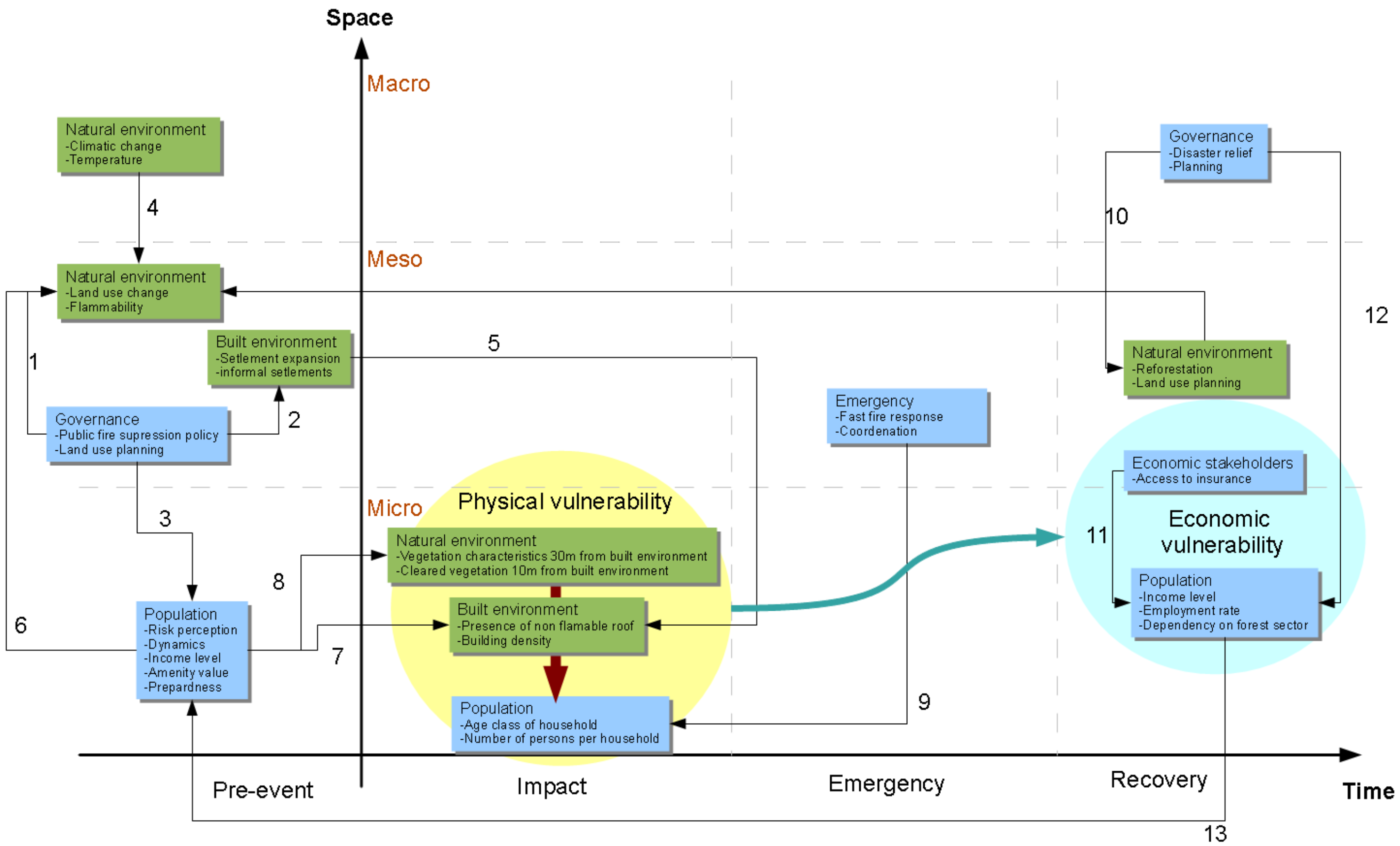

Figure 3.5: Conceptual framework for the assessment of vulnerability of people and build environment to forest fires in the WUI

The modified framework is now the basis to construct a dynamic qualitative model of vulnerability to forest fires. First a few words why such approach was taken. Investigating how different agents and objects shape the overall vulnerability requires necessarily the use of a dynamic approach. This approach allows the user to change at will selected parameters and observe the corresponding effect across the system components. Ideally, a quantitative analysis of a dynamic model would allow for more meaningful results. In the case shown here such analysis is pursued. This exercise is meant to set examples on how the original vulnerability framework produced by the Ensure project can adjusted for investigating dynamic links of vulnerability factors. For example, what parameter or combination of parameters can more effectively increase or reduce vulnerability? The overall structure of the model conceived is presented in Figure 3.6.

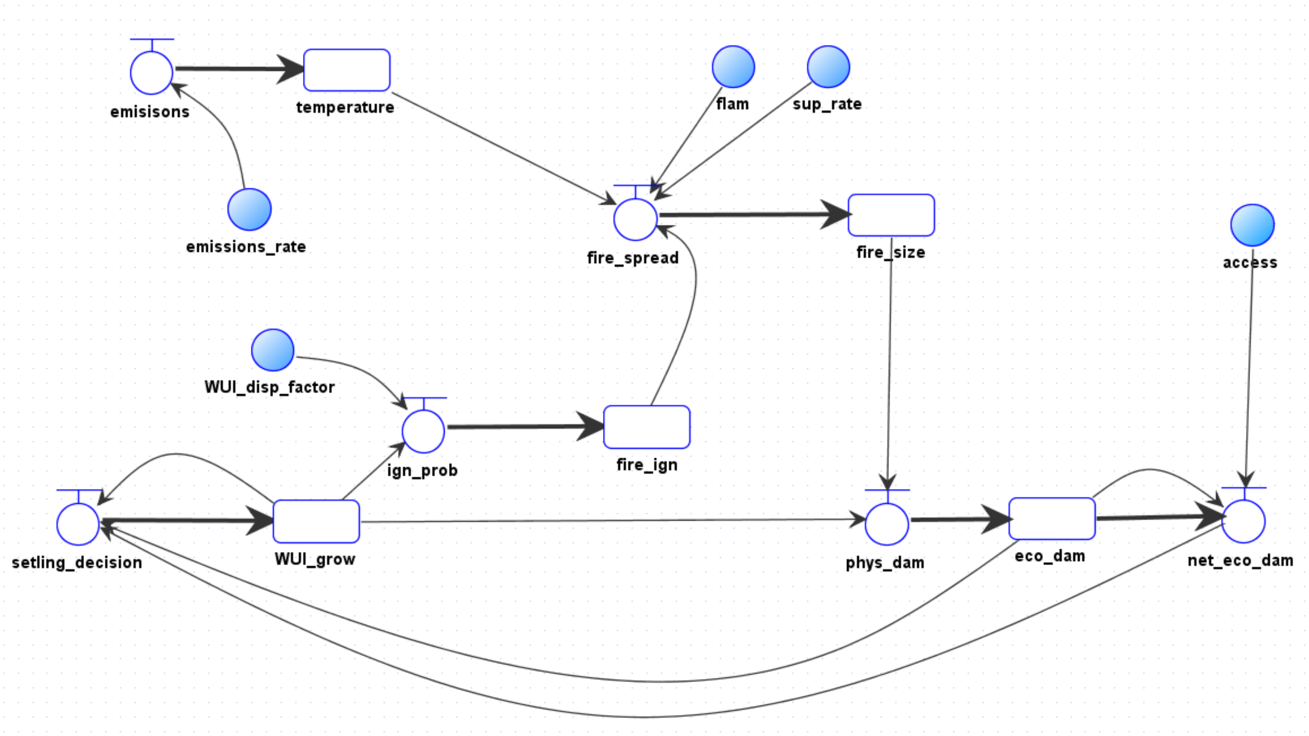

Figure 3.6: *Graphic representation of the operated model*

The model shows the dependencies between the variables temperature, fire size, fire ignition economic damages and WUI growth (represented by the squares temperature, *fire_size*, *fire_ign*, *econ_dam* and *WUI_grow* respectively in Figure 3.6). The dependency is of course not a direct one; for example, additional parameters such as emission rate (*emissions_rate*), flammability of the vegetation (*flam*), settlement development (*WUI_disp_factor*) or access to insure (*access*) (highlighted by blue circles in Figure 3.6) control the dynamics of the main variables. Main variables and additional parameters are included in the model via abstraction from literature results. For example, the density of settlements that intermingle with forest vegetation cover have been found to influence the fire ignition density as shown in Figure 3.7

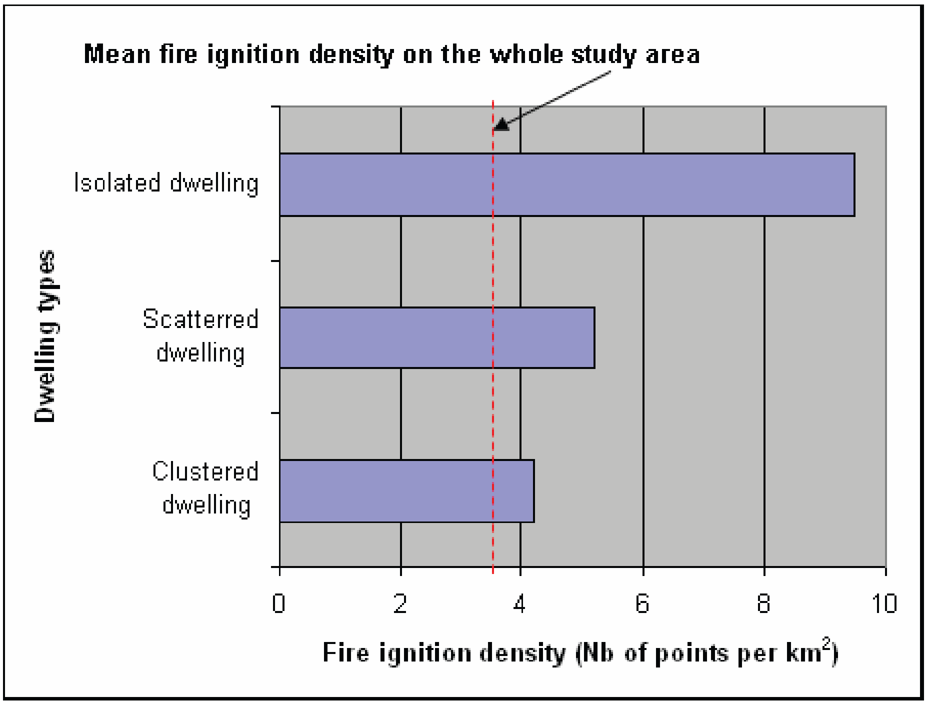

Figure 3.7: Fire ignition density value (Lampin-Maillet et al 2008)

For a case study in Southern France, fire ignition density values were found to increase greatly from clustered dwellings (4.2 fire ignition points per 1,000 ha), to scattered dwellings (5.2 fire ignition points per 1,000 ha) and finally to isolated dwellings (9.5 fire ignition points per 1,000 ha). This suggests that the spatial pattern of dwellings has a real impact on fire occurrence. Humans, and their spatial distribution, explain a part of the variability in the number of ignition points (Lampin-Maillet et al 2008). In our model the spatial pattern of dwellings is set by the parameter WUI_disp_factor that influences directly the probability of fire ignition represented by *ign_prob* in Figure 3.7.

We try to mimic the findings of literature by formulating *ign_prob = WUI_grow*(1-(1/WUI_disp_factor))* where *WUI_grow* is the total size of our settlement and *(1-(1/WUI_disp_factor))* the effect of settlement dispersion on ignitions so that when *WUI_disp_factor* decreases (this is more compact settlements) ign_prob increases. By changing the parameter WUI_*disp_factor* we can test the corresponding effect on fire ignitions across time.

A quick test shown in Figure 3.8 exemplifies how changing the WUI_disp_factor influences the probability in fire ignitions. For a WUI_disp_factor of 2 the range of ignition probabilities varies between 0.5 and 0.53 (lower panel). If we double the WUI_disp_factor, ignition probabilities range from 0.75 and aprox. 0.80. Note again that these are not quantitative numbers; they only depict a qualitative change towards higher ignitions probabilities in *WUI_disp_factor* increases. Similar exercises as the one exemplified where carried for the totality of parameters and variables that compose our model. Of particular interest in our model is the linkage of insurance access (access) and net economic damages (*net_eco_dam*) influencing the decision to construct new settlements in the WUI. This feature can be found in the lower region of Figure 2 where *net_econ_dam* links to s*ettling_decision* closing the "vulnerability" cycle of our model.

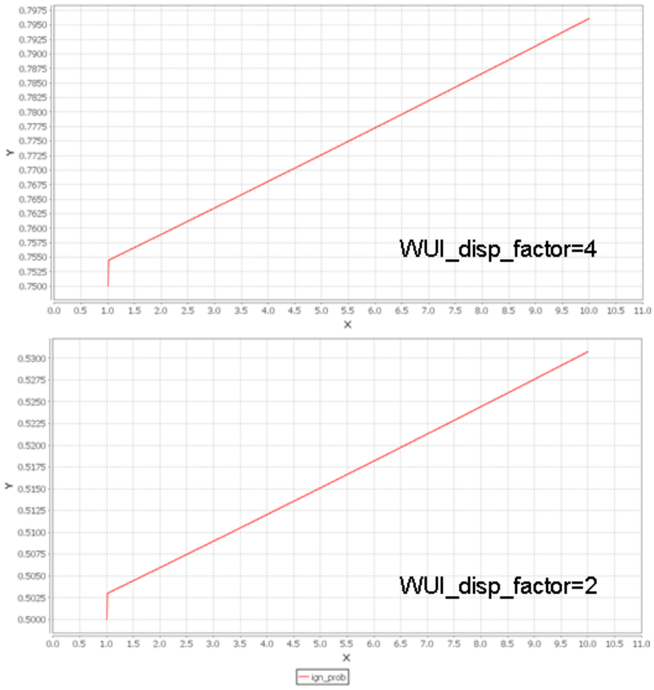

Figure 3.8: Evolution in ignition probability evolution for WUI_disp_factor=4 (top panel) and WUI_disp_factor=2 (lower panel) in time (x).

Although the positive feedback of insurance structures driving higher fire losses seems reasonable and consistent with previous studies, research has only begun to document situations in which the residential risk management calculus intersects with policy structures to create incentives for risk-amplifying behaviours (Collins 2005). Setting the mathematical formulation to mimic such complex aspect of fire prevention is therefore not a straightforward exercise. In the context of our modeling framework we have defined *net_eco_dam* as the net economic damages resulting from the application of an insurance access rate to the total expected damages (*eco_dam* in Figure 3.6). *Net_eco_dam* is therefore formulated so that *net_eco_dam = eco_dam-(eco_dam*access).* In a few words, the net economic damages are equal to total economic damages (eco_dam) minus the total economic damages that are offset by the application of an insurance access rate.

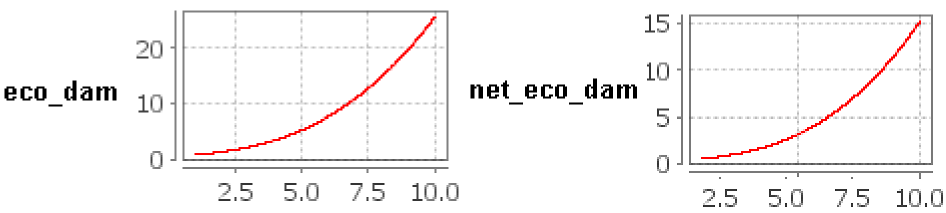

Figure 3.9: Total economic damage (left) and net economic damage (right) when and access insurance rate of 0.4 (access in Figure 2) is applied.

In Figure 3.9 we show the example of total economic damages and net economic damages after applying an access insurance rate of 0.4. The decision to settle in the WUI (*settling_decision*) in our model is a function the *net_eco_dam*, more specifically we construct settling decision so that *settling_decision = WUI_grow*(1/net_eco_dam).*

The ration *1/net_eco_dam* controls how much the WUI grows. If *net_eco_dam* assumes very high values then the WUI growth will be hindered since it is not economically feasible to build in the WUI*.* If *net_eco_dam* assume very low values, for example 0 (zero), this implies that all damages are covered by insurance practices and therefore the decision to settle in the WUI is made favorable.

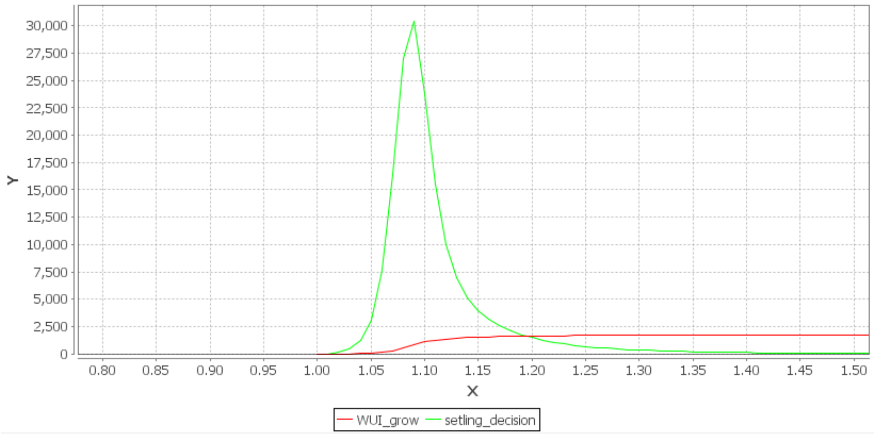

Figure 3.10 Dynamics of WUI growth and net economic damages

Results show that while losses can be compensated by the existence of insurance mechanisms (*net_eco_dam* in figure 3.10) settlement grows due to the substitution effect highlighted by arrow 13 in Figure 1. After a certain period, settlement growth originates losses that can no longer be compensated by relief mechanisms. With the growing magnitude of fire towards the end of the simulation (see Figure 3.10), settlement growth starts to stabilize.

Once this kind of interactions is understood, the model can be tested for its sensitivity (e.g. how strong the main variables react to a change in the parameters). For example, due to a consistent projected increase in temperature across the Mediterranean basin (Giorgi, 2007) and the time delays associated with atmospheric response, climate mitigation measures (represented by parameter *emissions_rate* in Figure 3.6), have limited effect in controlling losses from forest fires. Instead, socio-economic drivers of forest land-use and settlement planning significantly contribute to the intensity of losses. Management policies should therefore focus on modifying these parameters, for example, shifting away from highly flammable pine monocultures (represented by the parameter *flam* in Figure 3.6) and providing support to mixed forests with native fire resistant species has improved natural fire prevention in the Mediterranean area and also the range of economic markets to be explored (Bassi, 2008). The model also highlights how a change in access to insurance can result both in lower and higher losses rather than the generalized assumptions that access to insurance contributes to lower economic vulnerability.

The approach followed is an attempt to evaluate how multiple actors and objects interact in the context of forest fire hazard shaping physical and economic vulnerability. The challenge of linking cross scale (both in time and space) interactions is not trivial and more assessment needs to be done mainly in the fields of risk perception and individuals decisions. On the other hand, the physics of climate, vegetation and fire are now relatively well understood. This means that simple dynamic models as the one presented can be constructed to evaluate how decisions on climate mitigation, fuel loads reduction and fire fighting capacities influence vulnerability. In this respect the model highlights that although future climate variability plays a role concerning the intensity of forest fires, losses are shaped at a large extent by settlement dynamics and vegetation flammability.

4 Open conclusion

At the end of the Ensure project, some observations may be brought to the attention of readers regarding in particular the successes, strengths and failures of interdisciplinary work. It is a sort of "common sense" in the scientific community working on risks, hazards, prevention, that an interdisciplinary approach is required, and for a number of good reasons.

Some are rather self-evident: the multiple competences needed to study different phenomena (sometimes enchained), the various components of risk (hazard, exposure, vulnerability) that call for a variety of expertises.

Other reasons are less banal: we are tackling vulnerability and resilience of complex systems, across multiple spatial and temporal scales. No single scientific community or expertise is able to address those issues satisfactorily. With respect to the past, it can be said that interdisciplinary research has been accomplished; several teams with members of various disciplinary backgrounds have worked together in projects, just to mention those funded under the 6th and 7th FP.

In Ensure we did have an interdisciplinary team and we did encounter obstacles and constraints that other groups, in completely different sectors, have experienced as well (see Nicolson et al, 2002 and Lélé et al. 2005). The interesting fact about the quoted articles is that they are recent and they report about experiences of working and coordinating different scientific communities. We will ground here on their reflections to draw our own ones, based on the Ensure work.

First, the type of "interdisciplinarity" has to be clearly defined. In Ensure we did not face simple collaboration (the first level of "interdisciplinarity" according to Eigenbrode et al., 2007), and even not the focusing on a given task or problem (the second level), rather we had to first identify and define the contours of the problem (the third level). In fact we had to state what resilience and vulnerability meant for us and how we intended to convert the agreed upon interpretation into a way of measuring and assessing (see Winograd, 2007). The readiness to this type of collaboration and coordination was not equal for all participants, independently form partner/country/scientific background. Such readiness had more to do, as stated by Lélé et al. (2005), with the acceptance of the other, the willingness to cross disciplinary borders, and the capacity to select and simplify relevant knowledge in each own field in a form useful for the collaboration, rather than specific field of expertise or personal curriculum.

The scientific coordinator had certainly significant responsibility in the difficulties to make the various project parties interact and integrate rather than polarize on definitional issues or on divergent modelling perspectives. Yet, the project was a meaningful learning experience in this regard. We now agree with Nicolson et al., 2002, when they say that such a project should start with a prototype or a similar "close" model, readymade "position paper" on which to collapse different views and competences is certainly a valuable recommendation. The initial agreement on a prototype clarify since the beginning the role that each expertise may have in the project, and would set the expectations regarding its results. A sort of initial negotiation regarding the object, the objective and a baseline model to test must exist prior to the beginning of the teamwork and not just an output. Such negotiation would lead to a preliminary result that will be changed and even reversed at the end of the project, but which will compel partners to focus on common issues and way to accomplish expected results.

Another important point refers to allocating enough funding and time for smaller, partial meetings among some components of partners' teams. Those meetings allow for mutual comprehension, better mutual understand ding and construction of a shared view of the problems to be solved and the methodology to be developed. Such smaller group discussions were partially hold within the Ensure project to set issues related to vulnerability to landslides, volcanic crises and forest fires and proved to be particularly valuable.

To conclude with a positive remark, there was an agreement among Ensure partners that the framework constitutes a significant achievement of the project, which provides the possibility for each expertise to locate itself within a larger and more comprehensive context. At the end, engineers will continue studying what are construction features that make buildings and networks more or less vulnerable to earthquakes, floods or forest fires; in the meantime though, they will understand that the "root" causes and the drivers of such physical weaknesses have to be looked for elsewhere, in the legislative and institutional arrangements, in the capacity of governments and administrations to implement and achieve compliance with building codes, land use norms and regulations.

Volcanologists, seismologists, hydrologists will certainly continue to attribute high relevance to hazard maps availability; in the meantime though, in having to assess also the quality of produced maps, they will consider to what extent those maps are fit to support planners and decision makers in land use choices, relocation programs, development and redevelopment of urban areas and infrastructures.

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6 Appendix A : Presentation of the entire set of matrices developed within the Ensure project

Vulnerability assessment: the case of droughts

Compared to other hazards, droughts are specific in that they are slow onset events. First, this means that all tools available for early warning are crucial for lowering the vulnerability of potentially affected areas and communities. In the meantime, recurrent drought that characterizes in particular arid and semiarid regions can be (should be?) dealt with not only satisfying the increasing demand but also (mainly?) governing it, reducing water wastage and increasing the efficiency of water services. Considering extreme drought events, preparedness, in terms of implementing contingency plans in appropriate ways can significantly reduce the impact on populations.

Second, the slow development of the drought phenomena may render the distinction between physical and systemic vulnerability inconsistent, because it is hard to distinguish an "impact" moment, as the lack of water is experienced over time with cumulative rather than sudden effects on the one end; on the other because the damage is not due (or only to a very limited extent) to the drought itself, as to the lack of water services, which is considered in our framework as a consequence of losses, rather than the losses itself. In principle if water is available from tanks and other retain facilities, even though it does not rain, the consequences for different economic and social sectors may be much less relevant or even negligible.

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Vulnerability assessment: the case of floods

Vulnerability assessments of floods have advanced quite significantly in the last years, particularly with respect to physical and systemic aspects. Damage curves have been developed by various research centres around the world and already adopted by national authorities. The purpose has been to draw dangerous zones and estimate the expected level of damage in given areas. Such curves are obtained by correlating some features of the hazard (water depth most typically) with some characteristics of the building (most typically number of floors).

When developing and using vulnerability assessments to floods, one must take into consideration what type of flood are we considering, if mountain flash flood, with associated strong velocities and energies able to transport debris and sediment or plain floods, where the most relevant dimensions to be considered are the height of the water and the expected duration of the event. To a certain extent, then, particularly as far as physical and systemic vulnerability are considered, differences must be accounted for the two types of phenomena.

Another important aspect is related to the possibility of providing early warning to the population: in the case of flood (particularly floods in plains) the capability to forecast, model and alert both the civil protection and the population is an important parameter to take into consideration in the mitigation matrix.

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Vulnerability assessment: the case of earthquakes

As already mentioned and supported by references (see in particular Roberts et al., 2009), seismic vulnerability can be considered as the reference model for developing similar assessment tools for all other hazards. Seismic studies have been also among the first to introduce the resilience concept both for addressing what we call here systemic vulnerability (or the opposite of it) and the response capacity of organizations and communities (see Bruneau et al., 2003).

In the seismic field attention has been put also on the vulnerability of the historic patrimony, with attempts to establish assessments and retrofitting techniques that respect the traditional way of constructing buildings and monuments which still resisted several shakes over time.

Vulnerability assessment: the case of volcanic eruptions

Volcanic eruptions are somehow different from other cases as they are muti-hazard events, as different phenomena may be associated to them, particularly in the case of explosive activity. Therefore it is necessary in the matrices to account for the different phenomena (tephra, ballistics, lahars, etc.) as they stress differently the built environment. The current state of development of physical vulnerability assessments can be considered as intermediate for volcanic activity. Some recent studies, particularly after the Montserrat event, have provided some clues regarding the survival conditions inside houses and of the structures themselves under different phenomena and relative severity.

Furthermore it must be pointed out that some phenomena induce direct systemic damage simultaneously to physical damage. Ashes provide a good example: whilst they do not break road networks, they hamper though normal traffic, as they make the asphalt slippery and dangerous.

Another relevant aspect to consider particularly as far as resilience is considered is the potential duration of the event, which may torn communities' capacity to continue coping with a phenomena that is continuously hindering their efforts to return to a "normal" life.

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Vulnerability assessment: the case of landslide

Vulnerability assessment to the landslide threat is still at an initial stage. Very few attempts have been made to develop methodologies to assess the vulnerability of territories and communities to the landslide hazard. In many cases vulnerability is equalled to exposure and the expected damage results from the overlapping of the landslide hazard map to the exposed elements. But even in this case, few examples are available, as the same damage accounting after landslide is rather deficient.

This situation can be explained with a variety of reasons. First, the poor damage reporting is often due to the fact that damage to landslides is confounded with damage to floods, meteorological events, etc, as they may occur simultaneously; second, there is a large difference between types of landslides as classified by Cruden and Varnes (1996). In particular a relevant distinction should be made between fast and slow movements: while the latter may be extremely dangerous and leave little time for pre alerting systems, the second can be monitored and predicted to a certain extent and cautionary measures can be taken before the event actually occurs.

Different types of monitoring systems and early warning decisions must be made with respect to the two types of events, with a different treatment of contingency plans and decisions to evacuate.

Also the severity of damage may be different, as fast movement, including rock falls, debris and mudflows leave little room for saving goods (and many times also human lives) and their energy and velocity can be devastating.

In the application of the general methodology of the proposed framework, it was therefore decided:

To distinguish particularly physical vulnerability to the different types of movement; while in the case of systemic vulnerability the distinction between fast and slow movements has been kept.

The parameters and indicators reflect on the one side the application to the case of landslides of general arguments, particularly when mitigation capacity and post event resilience have to be considered. It must be brought in mind that landslides are local events as far as the hazard spatial scale is concerned. It is the most “local” event with respect to the other ones considered in the project.

The parameters related to physical vulnerability address the very little is known regarding how structures typology, material, quality of construction influence the final impact effect; while the parameters related to systemic vulnerability acknowledge the fact that lifelines are particularly vulnerable to landslides and may create local disruption and discomfort for relatively long time in mountain areas where redundancy of utilities and accesses is generally low.

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First Matrix: Resilience: Mitigation capacity

System	Component	Aspect	Aspect Parameters	Criteria for assessment
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard maps availability	yes/no; level of detail with respect to scale of decisions
		Available knowledge updating	Hazard maps updating	Frequency of updating
		Hazards monitoring	Yes/no; quality and distribution of monitoring networks	binary; expert judgement upon the quality of networks
		Integration of monitoring systems forecasting modelling systems	Yes/no; quality and reliability of forecasting models; match of monitored data to forecasting models	binary; expert judgement upon the quality of models; back analysis
		Structural defence measures	yes/no; quality of defences; state of maintenance	
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	yes/no ; updating frequency
			Risk maps and scenarios, including enchained events	yes/no
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	yes/no; mode of inclusion
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	yes/no; updated
			Traditional building practice based on hazard knowledge	yes/no; capacity to re-produce traditional techniques correctly
			Maintenance of building stock	yes/no
			Land use plans embedding risk mitigation and vulnerability reduction	yes/no; sectoral/comprehensive; specific/generic
			Implementation capacity	yes/no; frequency of inspections; trained personnel for inspections
			Integration to other measures (insurance)	yes/no
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	yes/no ; updating frequency
			Maintenance programs embedding mitigation	yes/no
			New projects based on hazard/risk assessment	yes/no
			Level of coordination among stakeholders	low/medium/high
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	yes/no ; updating frequency
			Retrofitting measures for existing production sites	yes/no
			New projects based on risk assessment	yes/no
			Na-tech explicitly accounted for in hazardous installations emergency plans	yes/no; expert judgement on quality
Social system (agents)	*People/individuals*	Evaluation of the capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	inexistant/average/good
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans
	Community and Instituions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of institutions of improving risk awareness and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	
			Education programs & media campaigns	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	

Matrix to assess mitigation capacity

Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)

System	Component	Aspect	Aspect Parameters	Criteria for assessment
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	yes/no; parameters assessing specific response potential to different stresses	hazard specific
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	yes/no; how natural ecosystems condition may worsen hazards' impact	hazard specific
		Vulnerability of ecosystems to mitigation measures taken during emergency	yes/no; how natural ecosystems may be impacted by mitgiation measures	hazard specific
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Vulnerability assessment of residential buildings	hazard specific (though generally considering material, age of construction, structural features, maintenance conditions
			Vulnerability assessment of public facilities	hazard specific, considering also content (machinery, documents, etc.)
			Vulnerability of the urban fabric	hazard specific (though generally considering building density, height of buildings, morphology, etc.)
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines	Vulnerability assessment of critical infrastructure	hazard specific; different for each lifeline
			Vulnerability due to physical interaction among lifelines	depending on location, age, degree of maintenance
			Vulnerability due to physical interaction with vulnerable buildings	depending on the type of damage that may affect or not lifelines
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	hazard specific, though generally considering both structures, machinery, stocked material
			Vulenrability due to dependency on lifelines	depending on the degree of dependance upon external vulnerable lifelines
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Location with respect to vulnerable buidlings, roads, industrial sites	location in conditions where damage to structures may affect people
			Preparedness	hazard specific
			Specific sensitivity to hazards (smoke; ash, heat, etc.)	hazard specific
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping
	Community and Instituions	Factors that may lead to large number of victims	Population density in vunerable areas	

Matrix to assess physical vulnerability

Third Matrix: Systemic vulnerability: Vulnerability to losses

System	Component	Aspect	Aspect Parameters	Criteria for assessment
Natural environmer	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	yes/no; parameters assessing specific response potential to different stresses	hazard specific
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	yes/no; how natural ecosystems condition may worsen hazards' impact	hazard specific
		Vulnerability of ecosystems to mitigation measures taken during emergency	yes/no; how natural ecosystems may be impacted by mitgiation measures	hazard specific
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Existance of public facilities and resources to face the emergency	yes/no; a scoring system can be developed depending on a hierachical assessment of resources relevance for emergency management
			Accessibility to vulnerable areas	redundancy; quality of roads; usability; expected travel time
			Accessibility to public facilities	existance in the area, redundancy; quality of roads; usability; expected travel time
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Existance of lifelines	yes/no
			Degree of interdependance among lifelines	redundancy; emergency devices; autonomous capacity
			Continuity plan for lifelines, individually and in a coordinated fashion	yes/no; considers all potential threats/does not
			Degree of dependance of critical public facilities from lifelines	redundancy; emergency devices; autonomous capacity
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	redundancy; emergency devices; autonomous capacity
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time
			Contingency plan for na-tech	yes/no; considers all potential threats/does not
			Business continuity plan	Yes/no
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	Access to understandable information	yes/no
			Trust in information provisers	yes/no or percentage
			Preparedness in case of event	yes/no
			Presence of impaired groups (elderly, sick persons, etc.)	yes/no; percentage and location
	Community and Institutions	Factors that may hamper effective crisis management	Existance of contingency plan fro threats at stake	yes/no; date of last production or update
			Training using the contingency plan	yes/no; frequency of training
			Overlapping responsiblities among agencies	Low/medium/high
			Established protocols for information sharing	yes/no
			Established protocols for use of resources to manage the crisis	yes/no/partial

Matrix to assess systemic vulnerability

Fourth Matrix: Resilience: response capability in the long run

System	Component	Aspect	Aspect Parameters	Criteria for assessment
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from damages	resilience of natural ecosystems to the stress provoked by the natural hazard(s)	refer to studies in ecology; hazard dependant
		Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	resilience of natural ecosystems to the stress provoked by human intervention in the attempt to prevent losses to settlements and infrastructures	refer to studies in ecology
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Temporary transferability of facilities relevant for the settlement/city community life and economy	Yes/no
			Existance of plans for reconstruction in case of severe destruction scenarios	Yes/no
			Existance of skilled workers/firms for repairs and reconstruction (example historic sites)	Yes/no; availability with respect to expected need
			Level of sharing among stakeholders of reconstruction plans	High/low; only formal/substantial
			Level of integration of physical reconstruction with community healing processes	High/low; room for interpreting in the new/restored setting the meaning of the destruction
			Relevance of potentially affected settlements in geographic/economic terms	Central/peripheral
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	yes/no
			In site devices for quick survey of damaged parts	yes/no
			Availability of spare materials for fast repairs	yes/no; time needed to bring on site spare materials
			Availability of personnel for repairs	on site/in distant areas; number of available technicians with respect to expected need
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	yes/no/partial; number of different stakeholders to be coordinated in repair efforts
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	applicable/not applicable
			Existance of funds for fast repairs	yes/no
			Existance of inspection and guiding personnel for correct repairs	yes/no/forecasted in the recovery plans
			Economic sectors	Diversified or concentrated on few sectors
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	yes/no/making part of ordinary practices
			Availability of private resources to resettle/repair	yes/no/support by public agencies
			Access to insurance	yes/no/percentage of coverage
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Aging population; low fertility rates
			Local condition of aged population	autonomous/not autonomous; relatively healthy/not healthy
			Employment rate	high/medium/low
			Annual population growth rate (over the last five years)	high/medium/low/negative
			Immigration index	high/medium/low/negative
			Social networking	high/medium/low/negative
			Criminality rate	high/medium/low
			Conflict among social/ethnic groups	high/medium/low
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	high/medium/low (from sociological surveys when available)
			Transparency in funds allocation	Existance of public information and independent control mechanisms
			Long term vision	Existance of strategic development/land use plans
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	Yes/no/percentage
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricoltural activity

Matrix to assess resilience

Risk: drought **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	Natural Hazards	Natural hazards identification and mapping	Hazard maps availability, reporting climatic and hydrological conditions in the area	binary	yes/no	yes (Ministry of Agriculture,Israel Meteorological Service)
				mapping scale	level of detail with respect to scale of decisions regarding land uses	suitable to decisions regarding agricultural and herding practices
			Hazard maps and assesment considers climate change	binary	yes/no	yes
		Available knowledge updating	Hazard maps updating	Frequency of updating	approx. every 5 years	yes
		Hazard monitoring	Yes/no; quality and distribution of monitoring networks	binary; expert judgement upon the quality of networks	yes/no; rainfall and hydrological network available/not available	yes (Ministry of Agriculture,Israel Meteorological Service)
		Integration of weather and precipitation monitoring systems with drought forecasting models	Are there early warning systems	relying on what type of indexes	indexes tailored to the context/not tailored	yes by the Israel Meteorological Service at the beginning of the winter. Yet it has a limited success of cerca 60%
		Structural defence measures	possibility and capacity to use additional water sources	availability/capacity to drill new wells; connect among acqueducts; runoff harvesting; waste water purification	mc of additional water	Yes
				capacity to reuse water	numer of reuse cycles	yes, three
			remediation projects for contaminated rivers	binary; clear timing of clean up programs	yes/no	partially, some remediation projects have been carried out; still problems with chemical contamination
			purification of reused water	degree of achieved quality	good/acceptable/insufficient	good
Built environment	Exposure and vulnerability of built environment	Inclusion of vulnerability and exposure assessments in land use plans	Risk scenarios availability	binary	yes/no	yes
			Risk scenarios integrating climate change and induced hazards (like fires)	binary	yes/no	yes
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	yes/no; mode of inclusion	binary; only formally/substantially with limitations and specific requirements	yes
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	building codes embed measures for water saving	yes/no	partially, faucet installation aimed at reducing the amount of water used and controlling the amount of water used during flushing
			Traditional building practice based on hazard knowledge	capacity to re-produce traditional techniques correctly	yes/no; judgement about the capacity to conform to the "code of practice"	Measured are implemented to increase insulation; Yet it is part of the climate and is not necessarily linked to droughts
			Land use plans embedding risk mitigation and vulnerability reduction	binary; sectoral/comprehensive; specific/generic	yes/no; expert judgement	Yes, by the Ministry of Agriculture
			Implementation capacity	pricing policy for wasting water	yes/no	Yes, by the Ministry of Agriculture
			Integration to other measures (insurance)	binary	yes/no	Yes
Infrastructure and production sites	Critical infrastructures	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of water system	Existance of double piping system for rain/grey water	yes/no	yes for many rural sttlements
				Maintenance programs embedding mitigation	yes/no; frequency of maintenance	yes, maily in chrge by the Ministry of Agriculture
				New projects based on hazard/risk assessment	yes/no	yes
				Treatment plants operationality	fully operational and frequently inspected/missing plants, lack of inspection procedures	yes. Enlargement of existing plans and new plans are constantly taking place
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	with respect to water crisis	yes/no	yes
			Production buildings and activities designed to save water	binary	yes/no	partially
			Self storage of emergency water	binary	yes/no	partially
Social system (agents)	People/individuals	Evaluation of the capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	degree	inexistent/average/good	good
			Early warning systems	information addressing all components of communiy(ies)	% of coverage	100%
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	inexistant/average/good	Overall good for the Jewish farmers and insufficient for the Bedouin farmers
	Community and Institutions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awerenees and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	degree	inexistent/average/good	good for Jewish community and average for Bedouins?
			Level of coordination among institutions	degree	low/medium/high	Level of coordination betweenthe Land-use administration responsible for most state-owned land in the Negev; the Jewish National Fund (JNF) responsible for the forested plots, Mekorot: the national water company, responsible for channeling drinking water from the center and northern parts of the country to the Negev and for the purification and channeling of sewage water from the Tel-Aviv metropolitan to the Negev, the Ministry of Agriculture: responsible for research and development and professional instructions, and the Ministry of Finance that introduced the "drought line" demarcating an area as prone to droughts, where farmers are guaranteed the return of expenses in case of droughts is generally good. High levels of solidarity between JFA members, makes JFA a powerful actor vis-à-vis the governmental and financial institutes.
			Councelling for best agricoltural and herding techniques	binary	yes/no	yes, the Ministry for Agricolture is responsible and programs do exist
			Education programs & media campaigns	frequency and coverage	very frequent/rare; extended to the entire population at risk/only to limited groups	frequent; addressing also the Bedouin community for shifting from extensive to intensive herding
				thaught at school in ordinary programs	yes/no	yes
				Cooperation among different ethnic communities	high/low/conflict situation	Both conflicts and cooperation between Jewish and Bedouin farmers and between institutional and governmental agents are frequent in the Negev. Theft of Jewish agricultural equipment, crops and water from Mekorot by Bedouins are a common scenario in the Negev, as well as illegal occupation of state-owned land by Bedouins. Evacuation of the invaders from the land that is cultivated, at least, once, is difficult following verdicts by the Israeli Supreme Court. In addition, if their tents are legally destroyed, the state pays compensation to Bedouins. Socio-economic relations between the Bedouin populations and Jewish institutions are characterized by mutual help and cooperation. Land-use authorities allow for sheep grazing on the state-owned lands, and JNF allows, grazing (subject to some restrictions) in its forests. The Ministry of Agriculture actively acquires permissions from the army for entering Bedouin herds into army training zones during the weekends. Bedouin and Jewish guides employed by the Ministry of Agriculture facilitate adequate professional instructions to the sheep owners and farmers. The interaction between the Jewish farmers and the Bedouins include purchasing the right to use waste water of Bedouin towns by the Jeasish farmers. Bedouin workers are widely employed by the Jewish farmers while Bedouin sheep owners purchase from the Jewish farmers the rights to graze on the wheat straw. Jewish farmers also directly sell to the Bedouin sheep owners straw, hay and grains.

Matrix to assess mitigation capacity to drought

Risk: drought

Second Matrix: Physical vulnerability: Vulnerability to stress (drought) and to losses (water scarcity crisis)

In the case of drought it seems that the distinction between physical and systemic vulnerability as for other hazards does not make sense.
First because of the duration of the event, that can last for several months; second because the actual "damage" is the loss of an ecological service (water) which provokes the loss or the scarcity of water in pipes and in rivers. So the two aspects of damage and loss of function seem to coincide

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	crops and other agricoltural products by type	relative resistance to lack of precipitation	number of days/minimum mm rain/year	Selected crops have a high resistance to droughts; may yield 10-20% more grains with given precipitation.
				dependence on precipitation	totally rain-fed/irrigation (reused water)	Long-term trend of increasing the water sources and irrigated area in the Negev results in high robustness of the Negev territorial system to droughts. Thirty Years ago 90% of the Negev's fields' crop was wheat; these fields could be used for sheep grazing after the harvest. Currently, half of the cultivated areas are connected to the irrigation systems and are not available for grazing during years when semi-industrial crops or vegetables are grown on these plots.
			sheep and goat	relative resistance to lack of precipitation	number of days/minimum mm rain/year	During severe droughts, when the grain did not reach maturation and harvesting is cancelled. Bedouin herds are allowed to graze on the un-harvested plots during these years, the sheep numbers will grow and their feeding during the next years becomes problematic. A decision to increase the herd due to the high food availability during extreme droughts will cause capital loss during consecutive "normal" droughts when food is less available.
			soil capacity to maintain moisture	type of treatment	tillage/no-tillage; use of organic matters: yes/no	The use of the no-tillage cultivation techniques and special machinery that increase the soil water storage result in an increase in the moisture content of the soil (Bonfil, 1999). Similarly, the addition of organic matter which serves to increase the moisture content of the soil (Cantón et al., 2004) may contribute to the "success" of certain fields. Higher moisture content may also characterize "sun-shaded" aspects such as the northern aspect in the Negev.
				type of rotation	using productions that deplate water content/save water content	The decision to sow a more drought-resistant crop such as barely instead of the more drought-sensitive wheat may determine future vulnerability as well as more general decision on rotation of crops within a field. Despite the general necessity of rotation that aims at reducing the risk of exhausting the fields and the development of diseases, rain-fed wheat may be affected during a next drought year.
		Vulnerability of ecosystems to mitigation measures taken during emergency	crops and other agricoltural products by type	vulnerability to emergency water sources (i.e. desalinized water)	high/medium/low	Emergency water (from runoff or sewage). Only purified sewage water is used. As a rtsult there is no risk of using this water.
			sheep and goat	vulnerability to emergency water sources (i.e. desalinized water) and emergency actions	high/medium/low	On a national level, desalinized water is used. Yet this water is mixed with ions before reaching the fields and thus risk that stem from lack of necessary cations and anions is avoided. As for sheep and goat, during severe droughts actually the food for herd increases leading to a more vulnerable situation
Built environment	*Exposure and vulnerability of built environment*	Factors that make exposed systems vulnerable to drought	Vulnerability assessment of buildings	type and maintenance of pipes; needed pressure to have water at taps	designed for dry climate/ordinary pipes; large pressure needed/low pressure	The existence of a double system (for domestic use and for agriculture) reduces the vulnerability of the system
				emergency water storage	yes/no	Local reservoirs of runoff and sewage water. Yet, one has to note that these systems are not designed for emergency periods but one there, they may be used during such periods
				minimal water need/day/type of building use	l/day/type of use: residential, hospital, school, other public facilities	DO YOU MEAN(?): shortage of water sources and water quata, inproper cultivation techniques.
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines)	Vulnerability assessment of water system	average lifelitime of wells	months	Inadequate planning of water usage; technical difficulties in operating the facilities used for waste water purification
				minimal threshold of water needed in tanks and reservoirs	cm	Since all water of the entire country is centrally controlled, over pumping and excess of water usage will ffect the entire country and may not be confined to one particular region
			Availability/capacity to use emergency alternative sources	binary; estimation of mc that may be addeded to the system	yes/no; mc	see above
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	degree of dependence of activity on water	high/medium/low	low; Since irrigated crops are sown prior to any knowledge regarding drought and are hardly affected by drought, only production that is based on rain-fed wheat and summer crops (which are mainly planted following a wet year) will be affected
				emergency water storage	yes/no; days of autonomy	see above
Social system (agents)	*People/individuals*	Factors that create discomfort for the population and as an ultimate resource the need to evacuate	Access to water sources per type and quality	degree	to all sources/partial/severely restricted	Both sources, dribking and purified water are used by both communities. Yet, as the usage of purified water necessitate high solidarity between the farmers and a strong "lobby" that will act to acquire bank funding, Jewish farmers can much easily invest in the costly facilities that purify wate and therefore are the main consumeres of purified water
			Population living in the driest areas	Number	l/day availble in drought conditions	No evacuation of people due to drought takes place. Yet, at a long run, immigration, especially of the Bedouin population from the rural settlements to the cities may take place due to reduced income
	Community and Institutions		Preparedness	degree	high/medium/low	high for the Jewish sector, medoium for the Bedouin sector
			Access to information about water saving strategies	degree of coverage	> 70%population/< 50% population	high for the Jewish sector, medoium for the Bedouin sector
			Contingency plan	binary	yes/no; shared among stakeholders/known by few	high
			Access to information about compensation and alternative sources of revenue	degree of coverage	> 70%population/< 50% population	Despite the compensation, the fields within the "drought line" do not yield income and the compensation cannot prevent the severe economical influence of drought on the farmers. Compensation relates to the expenses but not to the loss of revenue

note: there are some measures taken to reduce vulnerability to severe droughts that create vulnerability to more frequent droughts. (the vice versa can also be the case. Interesting)

Matrix to assess physical vulnerability to drought

Risk: drought; case study: the Northern Negev area

Fourth Matrix: Resilience: response capability in the long run

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Application to case study
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	Process of crops and other agricultural productions recovery	Needed time and water	Months; minimal mm precipitation	Hypothetically, drought may cause large abandonment of the Jewish settlements and immigration of the Bedouin population from the rural settlements to towns. However, such an extreme scenario is unrealistic. Droughts serve as a trigger for irrigating rain-fed plots and enforce Jewish farmers to increase the investments in water supply. By forming a lobby in favor of government investment in the development and transfer of water from the wetter parts of the country, and in additional local water sources, Jewish farmers substantially increased the system resilience. An increase of the urban population instead causes steady increase in the amount of the sewage water that serves in turn for irrigation (following purification)
		Capacity to introduce all mitigation measures envisaged in the first matrix during the window of opportunity opened during recovery	See first matrix as far as monitoring and structural defences are considered	binary	yes/no	
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Existance of plans/adjustments for recovery after severe drought periods	binary	yes/no	Droughts trigger the search for technical means to alleviate the effect of the drought, increases investments in water supply, and establishes economic mechanisms of crediting investments during the crises. Adaptation of new varieties of sheep, new insemination techniques, development of intensive sheep raising contribute to the resilience of the Bedouin sector to droughts. Investments and development of new water sources, extending the pipeline network, introducing new wheat varieties, increasing the moisture stored at the soil with the new agricultural techniques, all these consistently increases the coping capacity of the Jewish sector.
			Do adjustments reduce vulnerability to future droughts	binary	yes/no * *careful assessment needed regarding adjustments for frequent/severe droughts that may be counterproductive in case of frequent/severe droughts*	The use of purified sewage water for irrigation. Extension of the irrigated areas is the most important part of the northern Negev development during the last 20 years. The revenues from the irrigated crops are several times higher than that from the rain-fed crops, thus substantially increasing farmers' capacity to cope with the unfavorable weather conditions.
			Relevance of potentially affected settlements in geographic/economic terms	Type of settlement	rural low density areas/ urban areas/cities	In the project cities like Beer Sheva were excluded and attention was concentrated on the two types of settlements pertaining to the two communities. The Jewish farmers live in Moshav and Kibbutz structures, while the Bedouins are organised in families. Attempts to structure Bedouins' communities in settlements served with lifelines and other services succeeded only in part. While illegal occupation of State owned land is still very frequent and in those cases access to facilities is substantially less secure.
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	yes
			Possibility to improve the water system	binary	yes/no	yes
			Availability of extra water sources	binary and number	yes/no; mc estimated	yes
			Availability of technologies to reuse water	binary; type of technology	yes/no	yes reference to the table provided in the text
			Availability of technologies and practices to save water	biinary; type of technology	yes/no	yes, the use of the drip irrigation (saves half the amount of water in comparison to the traditional systems); use of domestic means that save domestic water use
	Production sites (other than agricolture)	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need within region/country	binary	yes/no	no
			Existance of funds for repaying costs and new investments	binary; amount	yes/no	The ministry of finance provides financial umbrella to the insurance of the farmers against the drought's hazard and, also, to immediate financial compensation provided to the farmers following droughts. Despite the compensation, the fields within the "drought line" do not yield income and the compensation cannot prevent the severe economical influence of drought on the farmers.
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of private resources to resettle/recover	binary	yes/no; support by public agencies/relying only on private funds	Yes, public funding. Strong lobbying by the Jewish farmers association.
	Community	Affected community's resilience to the consequences of a drought	Presence of elderly and particularly vulnerable people(sick, impaired)	percentage		
			Employment rate	degree	high/medium/low	high in the Jewish sector; much lower in the Bedouin sector
			Annual population growth rate (over the last five years)	degree	high/medium/low/negative	medium in the Jewish sector; extremely high in the Bedouin sector (the highest in the world)
			Immigration index	degree	high/medium/low/negative	Low
			Social networking	degree	high/medium/low	A positive social effect of the drought is the intensification of the intra-relationships and solidarity between the community members, especially in the aJewish sector.
			Conflict and cooperation among social/ethnic groups	degree	high/medium/low	Droughts affect interaction between the Jewish farmers and the Bedouin sheep owners. Jewish farmers may allow grazing while the Bedouin sheep owners may decide whether to purchase the right to graze on agricultural fields or rather to purchase hay to feed the sheep at the barn or paddock in their own property. The decision of the Jewish farmers to restrict grazing on agricultural fields may, on one hand, reduce the number of herds in the Northern Negev; on the other hand this may enforce new husbandry techniques. A decision of the sheep owners not purchase the right to graze on the fields may enforce Jewish farmers to use the straw as mulch.
	Institutions	Are institutions in charge of reconstruction transparent, reliable and trustable?	Degree of trust in institutions	degree	high/medium/low	high for the Jewsish farmers; medium for the Bedouins
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no	yes
			Long term vision	Existance of strategic development/land use plans	yes/no	yes
				Level of sharing among stakeholders of recovery plans and adjustments	High/low; only formal/substantial	Currently, half of the cultivated areas are connected to the irrigation systems and are not available for grazing during years when semi-industrial crops or vegetables are grown on these plots. The amount of fields available for grazing is thus constantly decreasing. Consequently, the pressure, on the Bedouin farmers, to switch from extensive to intensive sheep-raising is increasing. This is accompanied by Internal changes of the Bedouin society, higher education demand and refusal of the young generation to serve as shepherds. Yet, the reduction in the Bedouin sheep-feed areas is accompanied by higher yield of wheat from the plots irrigated a year before. Indeed, following crop rotation, wheat is often grown on plots that were used for irrigated semi-industrial crops or vegetables a year before. As a result, the amount of straw at these plots is substantially higher than on plots that were not irrigated. In this way the irrigated plots may compensate, at least partially, for the reduction in the amount of the fields available for Bedouin grazing.
				Compensation mechanisms integrate risk mitigation measures	yes/no	Currently, the investments of the Jewish farmers into new water sources are continuously increasing. The tendency of the Bedouin sheep owners to switch to intensive raising is also noted. We do not have yet a definite answer whether a reduction in the grazing area could enforce the switch from extensive to intensive sheep raising. Yet, our preliminary results point to such a possibility.
	Economic stakeholders	Willingness and capacity of economic stakeholders to reinvest in affected areas	Insurance coverage	Coverage	%	all Jewish sttlements; only a small part of the Bedouin farmers
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricultural activity	percentage on GNP (of the region/country)	Agricultural yield is responsible for above average GNP due to the Negev advantage in early maturation of winter crops and the high proces received for theses goods abroad

Matrix to assess resilience to drought

Risk: flood; Case study: Severn, flood 2007 **First Matrix: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard maps availability	binary	1. yes/no	
			Hazard maps scale	scale and level of detail with respect to planning decisions	county level, neighborhood level, single building level	
			Considers domino effects	Considers potential na-tech	yes/no, only partially	
			Hazard maps considers climate change	binary	yes/no	
		Hazard monitoring	Dos a monitoring network exist?	binary	yes/no	
			quality and distribution of monitoring networks	expert judgement upon the quality of networks	high/low	
		Integration of weather and flood detection and monitoring systems with hydraulic and hydrologica/hydrographic flood forecasting models	Does an instrumented flood detection and monitoring system exist (i.e. a hydrometric network) ? How much of the geographical area does it cover ?	Binary, % area coverage	Yes/No, <30%, 30-60%, >60%	Capacity to take preventative action for pluvial flooding is limited because of the time taken to react (especially at night-time) and short warning lead times. Capacity to respond to fluvial flood warnings is relatively good.
			are there early warning systems?	binary; quality	yes/no; expert judgement	
		Flood forecasting	Flood forecasting capability	Resolution capability	Low, medium, high	
		Flood warning	Is severe weather warning integrated with flood warning to lengthen the overall warning lead time ?	Binary	Yes/No	
			Flood warning timeliness	Warning lead time	Very short (<30 mins), short (30-180 mins), medium (181 mins - 12 hrs), long (>12 hrs)	
		structural defence measures	Do they exist, what is the defence standard	binary; Return Period for which protection is set	Yes/No, 50, 80, 100, >100 yrs	The Lower Severn sub-region has few raised structural flood defences (there are some low earth embankments and pumped drainage systems) to protect against fluvial flooding, although there are flood embankments around the edge of the estuary which provide a high level of protection against tidal flooding. Structural flood protection for fluvial flooding is largely impracticable because of floodwater displacement and transfer implications.
			Do protection standards take climate change into account ?	Binary	Yes/No	
			Condition of defences	Is condition assessed regularly (a) point installations: binary (b) linear defences: binary ?	(a) Yes/|No, %age in excellent, good, poor condition (b) Yes/No, %age in excellent, good, poor condition	Point installations include flood gates, pumping stations etc.
			Maintenance	(a) Does a systematic plan exist for maintenance: binary (b) is maintenance budget guaranteed: binary ?	Yes/No, Yes/No	
			Is space available to construct, reconstruct or realign defences ?	Binary	Yes/No	
			Flood retention areas (a) Do they exist ? (b) Does land use planning allow for potential retention areas for the future to be protected from development ?	(a) Binary (b) Binary	Yes/No, Yes/No	
			Are natural flood buffer zones maintained and/or reinstated when lost ?	Binary	Yes/No	These include beaches, marshes, mudflats and natural habitats
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	binary ; updating frequency	yes/no; every 5 ys/only after floods	
			Risk maps and scenarios, including enchained events	binary; RP considered	yes/no; only frequent events/also rare events	
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations and specific requirements	As the floodplain settlements of Gloucester and Tewkesbury have grown in response to economic growth, so they have further extended in some cases into the floodplain because of the absence of alternative development land in attractive locations. Even so since 1947 the planning and development control system has restrained development in flood zones.
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	binary; updated	yes/no; judgement of effectiveness upon "age" of rules with resepct to state of the art	Capacity to control building standards came with the introduction of building codes which have a long history in the UK. These codes, now well enforced, will have avoided gross instances of a lack of basic structural integrity and resilience to flooding. Today's building codes do not include detailed flood resilience standards but there are plans to correct this.
			Rules for retrofitting	Binary	Yes/No	
			Flood resilience built into new projects and programmes	Binary	Yes/No	
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	yes/no; judgement about the capacity to conform to the "code of practice"	
			Maintenance of building stock	binary; economic incentives	yes/no; exist/not foreseen	
			Land use plans embedding risk mitigation and vulnerability reduction	binary; expert judgement	binary; sectoral/comprehensive; specific/generic	In response to the spreading of urbanisation into the countryside in England and Wales, in 1947 the nation introduced a universal land use control system (the Town and Country Planning System). This required most development proposals to acquire planning consent before development could take place.
			Implementation capacity	binary; frequency of inspections; trained personnel for inspections	yes/no; availability of budget for personnel to advice and inspect	
			Integration to other measures (insurance)	binary	yes/no (what conditions)	Flood insurance premiums have a limited fit to level of flood risk. Flood insurance companies do not yet reduce premiums for those who have installed resilience measures.
			Projects of access ways to and within hazardous areas	binary	yes/no	It has proved very difficult to develop a transportation system for the Lower Severn which is not flood prone. As a consequence many roads and some rail lines are flooded from time to time. Adoption of Sustainable Urban Drainage Systems (SUDS) has now become mandatory and this will help limit surface water flooding of road systems.
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary ; updating frequency	yes/no; anytime new project/repair needed/only after floods	Capacity to locate utility installations in flood-free locations has been limited. There has been a long-standing tendency to locate utility installations on areas of low-lying ground which were apparently 'waste' land and not used for other purpose - developing a legacy of flood prone infrastructure
			Maintenance programs embedding mitigation	binary	yes/no	
			New projects based on hazard/risk assessment	binary	yes/no	Detailed studies have recently been done to develop and publicise flood resilience and flood resistance measures for critical and other infrastructure (McBain et al., 2010). New infrastructure will need to proceed through flood risk assessment procedures in future and processes now exist for this.
			Level of coordination among stakeholders	expert judgement	low/medium/high	
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	binary ; updating frequency	yes/no; anytime new project/repair needed/only after floods	
			Retrofitting measures for existing production sites	binary	yes/no	
			New projects based on risk assessment	binary	yes/no	
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary; expert judgement on quality	yes/no; in generic terms/through detailed assessment	
			Commercial flood insurance	Binary; extent of coverage	Yes/No, low/medium/high	
Social system (agents)	*People/individuals*	Evaluation of the capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	questionnaires, surveys, judgement after event	Negligible or low/average/good	In Gloucester 34.9% of residents have lived in their house for less than 5 years (the equivalent statistic for Tewkesbury is 35.2%) (Gloucestershire County Council 2009). Although these statistics do not relate specifically to the portion of these settlements which are flood prone, they are an indicator of the degree to which the local population has the capacity to manage flood risk and is likely to be inexperienced in flood risk and its successful management. Such residential mobility is a feature of a relatively prosperous urban society of which the Lower Severn area is part.
			Access to flood information including flood maps, explanation of warning codes, appropriate actions	Binary; map quality	Yes/No; map quality good/fair/poor	
			Flood insurance	Binary; coverage	Yes/No, low/medium/high	
			Training and experience of population/communities	Qualitative judgement	Low/medium/high	
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	Negligible or low/average/good	Everyone with access to the internet (internet access is around 80%) is able to access indicative flood maps provided by the Environment Agency. By clicking on the precise location of a property, a property owner can read an assessment of the risk of flooding to that property. This data is publicised by the Environment Agency at local farmers' markets and special flood fairs, as well as in other ways.
	Community and Instituions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	binary and level of involvement	yes/no; only formal/encouraged participation	
			Education programs & media campaigns	binary and frequency	yes/no; regularly carried out/only occasionally	flood risk awareness and how best to prepare for flooding is not as well comprehended as it needs to be in these communities despite recent flood events. Through mechanisms such as the above roadshows and the Flood Information Network, local capacity has been developed to introduce local people to flood products which can increase the resilience of homes and other structures to flooding.
			Awareness programs as part of ordinary teaching programs	binary	yes/no	
			Capacity to invest in mitigation	Qualitative judgement	Low/medium/high	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	judgement	good/partial/low	
	Economic stakeholders	Level of preparedness of key economic stakeholders	Capacity to invest in mitigation	Qualitative judgement	Low/medium/high	
			Business continuity plans	binary	yes/no	

Matrix to assess mitigation capacity to flood

Risk: flood; Case study: Severn, flood 2007 **Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	Are different crops/agricolture productions vulnerable?	height of water; quality of flooding water; duration of flood	mt; concentration of contaminants; days	Average agricultural flood damage cost were about £1,150 per flooded hectare when weighted by land use
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	Is there a possibility of solid trasport mechanisms	binary/expected volume of material	yes/no; mc	
		Vulnerability of ecosystems to mitigation measures taken during emergency	River diversions taken to reduce the hazard severity may subtract water from areas that need it?	binary	yes/no	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Buildings structural vulnerability	timber/mud/stone/bricks/reinforced concrete	timber/mud/stone/bricks/reinforced concrete	Different depth-damage curves for each house type to be allocated to properties in flood risk zones.
				Number of floors	1/2/ >2	Number of high rise buildings is very low in terms of proportion of total.
				Level of the first floor with respect to expected flood	lower level/same/higher level	
				Existance of basement	yes/no	
			Properties within flood risk zone	Number and type of properties	Numbers from survey or secondary data	
			Position with respect to hazardous zones	Distance and position with respect to expected flood height	in the rapid inundation zones/at higher levels	It was the strategic position of Gloucester at a bridging point of the River Severn that led to the creation of the original settlement which then gradually spread out the wide estuarial floodplains. The town of Tewkesbury has similar origins being located strategically at the confluence of the Rivers Severn and Avon. This town has a population today of 10,000 and its growth and development has been very significantly constrained by the flood risk zones which surround it.
			Content of buildings	valuable objects in first floors	yes/no; type of valuable objects	
			Resistance and resilience of structural mitigation measures	Vulnerability to stress, maintenance regimes etc.	Qualitative judgement - low/medium/high	
			Non-structural mitigation measures e.g. early warning systems	Binary	Yes/no	
			Proximity to hazardous land uses	Type of land use and distance	Estimate of distance e.g. <500m, 500m - 1,000m etc.	
			Vulnerability assessment of public facilities	As for buildings but distinguishing by function		
			Vulnerability of the urban fabric	Consiering entire neighborhoods	Population density: high, medium, low	Average house damage insurance claims were £30,000 - £40,000
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines)	Water treatment plants; electical power plants; other lifelines plants	Distance and position with respect to expected flood	in the most critical zone/in a rarely flooding zone	The principal vulnerable installation is the Mythe Water Treatment works which was flooded in 2007. Physical damage to these works are estimated at £29.6 millions, without considering costs o distribution of water bottles. The Castlemeads Electricity substation was also flooded.11 Sewage Treatment Works and 40 Sewage Pumping Stations were flooded and all had to have equipment replaced afterwards.
				Ordinary maintenance	yes/no	
				Existance of emergency provisions to protect from floods	yes/no	The much larger Waltham Electricty Station supplying millions of consumers cam within 4 cms of flooding but was saved from flooding by emergency resilience measures
				Na-techs are considered in emergency procedures	yes/no	
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	Distance and position with respect to expected flood	in the most critical zone/in a rarely flooding zone	500 businesses directly affected by flooding
				Existance of emergency provisions to protect structures from floods	yes/no	
				Na-techs are considered in emergency procedures	yes/no	
				Existance of provisions to protect stocked material and machinery	yes/no	
			Vulnerability due to dependence on lifelines	Qualitative judgement	Low/medium/high	
			Proximity to dangerous land uses	Type of land use and distance	Estimate of distance e.g. <500m, 500m - 1,000m etc.	
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Location with respect to vulnerable buidlings, roads, industrial sites	People that may be trapped in flooding buildings of different types (residential, public, etc.)	number of people; location in maps	The potential of floods to kill people in the Lower Severn area is normally low because flooding is usually shallow. Two people died in the summer 2007 floods in Gloucestershire as an indirect effect of flooding.
			Preparedness	People know what to do in case of flood warning	yes/no; extent of compliance with norms in emergency plans	
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	number of people; location in maps	
			Depth of flood dangerous for individuals	Curves depth/individuals stability		
			Number of storeys in buildings where people live	Single-storey buildings e.g bungalows	%age of housing stock which is single storey	
			Temporary houses with low robustness hosting people	Caravans/mobile homes/chalets	Number of people living in these	
			Lack of high level exit routes and safe havens for people to escape		Yes/no	
	Community and Instituions	Factors that may lead to large number of victims	Population density in vunerable areas	Population density in different hazard areas	Maps	
			Numbers of tourists/visitors in vulnerable areas	difficulties to comply with evacuation orders and knowing what to do	Number of tourists/visitors	

Matrix to assess physical vulnerability to flood

Risk: flood; Case study: Severn, flood 2007 **Third Matrix: Systemic vulnerability: Vulnerability to losses**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environ	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	Are crops and other agricoltural productions vulnerable to contaminated water	by type of production and concentration/type of contaminant	detailed analysis of potential contaminants sources in the area needed	
			Areas that may be vulnerable to secondary contamination	along the river, considering dispersion mode of contaminants	Contaminants, rock, stones, boulders, mud; transportation pocesses	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Existance of public facilities: hospitals, fire brigades, emergency control rooms	yes/no; functional capacity of such facilities	assessment of functional potential of facilities	
			Facilities which posses underground elements such as access routes, basements, tunnels	Binary, extent	Yes/No; lengths of routeways, proportion with underground facilities	
			Lack of safe (e.g. high level) exit routes from underground facilities or from flooded buildings	Binary, extent	Yes/No; lengths of routeways, proportion with underground facilities	
			Range of service of public facilities	Importance of facilities in the potentially stricken areas	Local facilities/regional/national relevance	
			Accessibility to vulnerable areas	redundancy; quality of roads; usability; expected travel time		10,000 motorists stranded on motorway system. 500 rail passengers stranded. Tens and thousands more with disrupted travel for several weeks. Aaccess to Tewkesbury was maintained by a single rail line during the summer 2007 floods.
			Accessibility to public facilities	redundancy; quality of roads; usability; expected travel time		
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Existance of lifelines	binary	yes/no	
			Degree of interdependance among lifelines	level of redundancy; binary	high redundancy; emergency devices exist/do not; autonomous capacity exist/does not	
			Continuity plan for lifelines, individually and in a coordinated fashion	binary	yes/no; considers all potential threats/does not	
			Degree of dependance of critical public facilities from lifelines	binary	autonomous plants exist/do not; alternative resources available/not available	
			People and areas depending on lifelines in potentially affected zones	number/area dimension	number of customers who may be affected; geographic area	Number affected through loss of potable water supplies: 135,000 homes or 350,000 people for 17 days: i.e. 340,000 people outside the flood risk zone. Adaptation comprised providing large number of bottled water supplies but not without availability problems in some areas.
			Duration of outages	hours/days	few hours/> 24	Number affected by loss of electricity power supplies: 48,000 homes or 111,840 people for up to 2 days: i.e. c100,000 affected outside of flood risk zone.
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	binary	autonomous plants exist/do not; alternative resources available/not available	500 businesses directly affected by flooding, additional 7,500 businesses outside of flood risk zone affected by loss of water supplies for 17 days
			Transferability to other production site(s)	Binary or degree	Yes/no or none/partial/most	
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time	only 1 road/more alternatives; local/regional/state roads; <2hours/>4 hours	Relatively high level of redundancy in road system (except many roads normally run near capacity at rush hour) and for lateral routes across Severn valley which will have involved lengthy diversion routes (e.g. 100 kilometres). Traffic diversions enabled transferability of travel in many cases but increase in costs as a consequence.
			Contingency plan for na-tech	binary	yes/no; considers all potential threats/does not	
			Business continuity plan	binary	yes/no	Business continuity planning has become relatively well developed in the UK in the past decade and so we would expect many flood risk firms to have considered how they would ensure business continuity during a flood disaster. How many would probably not have considered prolonged loss of potable water supplies caused by flooding in the summer 2007 floods.
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	Access to understandable information	binary and redundancy	yes/no; radio and TV/special telephone number/internet	Everyone is able to obtain geographically specific flood warning information and flood advice (including on flood resilience measures) by telephoning the Environment Agency's FLOODline. Radio information is also available.
			Trust in information provisers	binary or degree	yes/no; good/average/ low	
			Preparedness in case of event	degree	good/partial/low	People received severe weather and flood warnings but most did not expect utilities to suffer outages and so they were not prepared for this in most cases.
			Existance of individual/community plan for evacuation	binary	yes/no	
			Availability of temporary shelters	degree	good/partial/low	825 homes (1950 people) were evacuated to rest centres provided by the local authorities
			Availability of temporary location for patients/ill people	binary	yes/no	
	Community and Institutions	Factors that may hamper effective crisis management	Existance of contingency plan fro threats at stake	binary; date of last production or update	yes/no; recent/old	
			Training using the contingency plan	binary; frequency of training	yes/no; every 2 years/>2 years	
			Overlapping responsiblities among agencies	degree	Low/medium/high	
			Established protocols for information sharing	binary	yes/no	
			Established protocols for use of resources to manage the crisis	degree	yes/partially/no	
	Economic stakeholders	Economic stakeholders preparedness to face crises	Capacity to run economy and respond to crises	degree	yes/partially/no	
			Capacity to invest in recovery and take preventive actions	Binary or degree	Yes/no or none/partial/high	

Matrix to assess systemic vulnerability to flood

Risk: flood; Case study: Severn, flood 2007 **Fourth Matrix: Resilience: response capability in the long run**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application to case study
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from damages	Resilience of crops and other agricultural production to floods	Depending on depth and duration of flood water contamination and type of crops/production	Resilient/partially resilient/non-resilient	
		Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	Water quality in river	Binary	Remediation required/not required	
		Structural defences	Retention areas	binary/legal provisions	can be accomodated/cannot; legal impediments to taking/subtracting to development	Central government and the Environment Agency are following a flood risk management strategy called 'Making Space for Water' which is based on the concept of addressing flood hazards by employing a creative mix of structural and non-structural flood measures (Defra 2005).
			Levees	binary/funding	can be built/cannot be built; funding mechanisms in the reconstruction program	
			Demountable flood defences	Applicable: binary, available: binary	Yes/No, Yes/No	
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	New development and refurbishing programs include risk prevention as a routine/everyday practice	degree or extent	yes/partially/no	Detailed formal flood risk assessment procedures for siting of new buildings exist in the study area and the whole of England and Wales (DCLG 2010). These must be undertaken at a range of resolutions from strategic to site scales. Even so, 7% of new dwellings constructed in 2008 were located in high flood risk zones in South-West England which is the planning region within which Gloucestershire is located
			Detailed analysis of damage	degree and scale	yes/partially/no; at individual building/neighborhood/municipal scale	Detailed damage analysis at individual building scale has been carried out
			Building codes address flood risk for new construction and retrofitting	degree; compliance	yes/partially/no	However, flood resilience measures are not yet included in these building codes but will be in the next few years. There are now about 400 'flood products' on the market which property owners can purchase and install. So far relatively few properties have been retrofitted with flood resilience measures in the case study area although a few have.
			Availability of partial relocation programs during reconstruction for the most critical situations	binary	yes/no	Not known
			Ability to incorporate recovery/resilience measures in future urban redevelopment plans	Binary, degree	Yes/no, none/partial/high	
			Level of sharing among stakeholders of reconstruction plans	binary	High/low; only formal/substantial	The Environment Agency's is working on a number of key flood alleviation schemes, which amount to a further £5.2 million of activity. A wide range of jointly-funded project drainage and culvert works, de-silting, the raising of banks and flood reinforcement are being carried out to reduce the county's vulnerability to flooding. The County Council is working closely with the district and borough councils on over 50 major drainage improvement projects which will cost a total of £1.9 million
			Existence of skilled workers for reconstruction activites	degree	yes also with specific skills/yes/no	important to understand whether or not there are skilled workers for example in the sector of historic buildings restoration
			Relevance of potentially affected settlements in geographic/economic terms	degree of relevance	Central/peripheral	
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	
			In site devices for quick survey of damaged parts	binary	yes/no	
			Availability of spare materials for fast repairs	binary; time needed to bring on site spare materials	yes/no; < a day/>1 day	
			Availability of personnel for repairs	binary; number of available technicians with respect to expected need	on site/in distant areas; proportional to needs/few workers	
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	degree; number of different stakeholders to be coordinated in repair efforts	yes/partially/no; protocols among all companies or coordinated by authorities/limited agreements	
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	binary	applicable/not applicable	
			Existance of funds for fast repairs	binary	yes/no	
			Existance of inspection and guiding personnel for correct repairs	binary	yes/no/forecasted in the recovery plans	
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	Gloucestershire has a diversified urban economy according to the Provisional Economic Strategy 2008-2015 (Gloucestershire First 2007) but the rural economy remains too dependent upon the agricultural sector.
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	binary	yes/no;making part of ordinary practices/exceptional	
			Availability of psychological and physical support for those with special needs	Binary; degree of support	Yes/no, good/fair/poor	
			Level of skills and capacity to learn and adapt	Qualitative jjudgement	Low/medium/high	
			Availability of private resources to resettle/repair	binary and level of support by public organisations	yes/no; higly supported/lack of advisory personnel	Income polarisation is a persistent problem that has proved resistant to reduction. Gloucestershire has small pockets of deprivation (financial as well as other forms of deprivation). A range of welfare and other policies exist which seek to target this problem but success has not yet been achieved.
			Access to public relief funds, and funds and advice from public organisations	Binary, level of support	Yes/no; high/medium/low support	
			Access to insurance	binary; percentage of coverage	yes/no; %without insurance	In Gloucestershire, 1,300 houses suffered significant contents damage, and of these 270 had not purchased contents insurance (i.e. 20.8%)
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	age groups and fertility	Aging population; low fertility rates/young	
			Local condition of aged population	percentage of autonomous and healthy population	autonomous/not autonomous; relatively healthy/not healthy	
			Employment rate	degree	high/medium/low	
			Annual population growth rate (over the last five years)	trend	high/medium/low/negative	
			Immigration index	new immigrants/emigrants	high/medium/low/negative	
			Social networking	qualitatie judgement	high/medium/low/negative	
			Criminality rate	degree	high/medium/low	
			Conflict among social/ethnic groups	degree	high/medium/low	
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	degree	high/medium/low (from sociological surveys when available)	
			Transparency in funds allocation	binary	Existance (yes/no) of public information and independent control mechanisms	Grants are now available to the public for installing flood resilience measures.
			Ability to learn from past events	degree	high/medium/low	
			Long term vision	Existance of strategic development/land use plans	yes/no/only formal	
			Capacity to avoid income polarization	degree	existence of specific plans/generic statements	
			Corruption	degree	abnormal/average/minimal	
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage for direct damage and loss of workdays	binary; percentage of coverage	yes/no; %without insurance	
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricoltural activity	percentage	
			Access to knowledge about flood resistant structures	degree	high/medium/low	
			Access and information about funds for reconstruction	degree	high/medium/low	
			Degree of diversification and capacity to spread risks	degree	high/medium/low	

Matrix to assess resilience to flood

Risk: Landslides **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Comments
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Landsilides hazard maps availability	binary; scale of detail	yes/no; local/regional	
		Available knowledge updating	Hazard maps updating	Frequency of updating	on the basis of regular surveys/ only occasionally	
		Hazard monitoring	are landlsides adequately monitored?	binary; quality and density of monitoring devices	yes/no; expert judgement	
		Connection of weather and rainfall monitoring connection to forecasting models	existence and quality of early warning systems for predictable landslides types	binary; expert judgement upon the quality of models; back analysis	yes/no; match of monitored data to forecasting models	
		Structural defence measures	existance and quality of structural defences/drainage works	binary; expert judgement; movement status	yes/no; quality of defences; state of maintenance	
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	binary; updating frequency	yes/no; any time new buildings are built/only occasionally	
			Risk maps and scenarios, including enchained events	binary	yes/no	
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations and specific requirements	
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	binary;attempt to correlate between buildings characteristics and damage due to landslides	yes/no; taking/not taking into account damage accounting in specific databases	
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	yes/no; judgement about the capacity to conform to the "code of practice"	
			Maintenance of building stock	degree	good/average/poor	
			Land use plans embedding risk mitigation and vulnerability reduction	binary; sectoral/comprehensive; specific/generic	yes/no; expert judgement	
			Integration to other measures (insurance)	binary	yes/no	
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary ; updating frequency	yes/no; each time new projects are drawn/only occasionally	
			Maintenance programs embedding mitigation	binary ; updating frequency	yes/no	
			New projects based on hazard/risk assessment	binary	yes/no	
			Level of coordination among stakeholders	degree	low/medium/high	
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	binary ; updating frequency	yes/no; each time new plants or transformation of existing ones occurs	
			Retrofitting measures for existing production sites	binary	yes/no	
			New projects based on risk assessment	binary	yes/no; special provisions for hazardous plants/generic rules	
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary; expert judgement on quality	yes/no; good/poor quality	
Social system (agents)	*People/individuals*	Capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	degree	inexistant/average/good	
			Early warning systems	information addressing all components of communiy(ies)	% of coverage	
			Individual preparedness	availability of masks and sholves	yes/no	
			Known evacuation procedures	binary; training	yes/no; training every few years/ only occasionally	
	Community and Instituions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	degree	low/average/high	
			Education programs & media campaigns	binary; frequency	yes/no; every two years/only occasionally	
				embedded in school programs	yes/no; every two years/only occasionally	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	low/average/high	
	Economic stakeholders	Economic capacity to mitigate of the various stakeholders; the access to financial resources for mitigation	GDP; GVA (Gross added value, measure of productivity and size of economy)	level	rich/average/poor country	
			extent of marginalized groups	dimension of poverty/marginalization	percentage of people living with less than x/year	

Matrix to assess mitigation capacity to landslides

Risk: Landslides

Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters value/categories	types of landslides: slow movement: lateral slide	slow movement: rotational/translational slide	rapid movement: debris flows	rapid movement: mudflows	rapid movement: rock falls	Scoring
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	presence of vegetation and forests on sliding slopes	binary; coverage and type	yes/no; % and type	0.5	0.5	1	1	0	
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	slope morphology	channels	spread/rare; depth			1	1	0	
		Vulnerability of ecosystems to mitigation measures taken during emergency	presence of ecosystems that may be endangered by lava flows deviations	binary; type	yes/no; type of vegetation and other species	1	1	1	1		
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	roof	connection to structure	good/poor						
				shape	large inclination/plane					1	
			structure	material	steel, reinforced concrete, masonry (different types), other			1	1	1	
				type of connection among parts	good/poor	0.5	0.5	0.5	0.5	0.5	
			foundation	depth and type	non-existent, deep, superficial	1	1	1	1	1	
			spans between resistant elements	distance in m.	> 3 mt; < 3 mt (for masonry mainly)	0.5	0.5	0.5	0.5	0	
			shape	openings	number and dimension of windows/doors	0	0	1	1	0	
				quality of openings	may be easily sealed/not	0	0	1	1	0	
			maintenance	building conditions	very poor/ good	1	1	1		1	
				with respect to dangerous channels	parallel/perpendicular	0	0	1	1	0	
				position with respect to the moving mass	on the movement mass/below/below at a distance/ lateral	1	1	1		1	
			Vulnerability assessment of public facilities	as for buildings							
			Vulnerability of the urban fabric	?							
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines	electricity and communication	position of lines with respect to the mass movement	across the moving mass/below/lateral	1	1	1	1	1	
				power station, telecom centre	see buildings assessment	1	1	1	1	1	
			gas	position of gas conducts	across the moving mass/below/lateral	1	1	1	1	1	
				connection to vulnerable buildings	vulnerable buildings/not vulnerable)	1	1	1	1	0	
			water and sewerage	position of water pipes	across the moving mass/below/lateral	1	1	1	1	1	
				pipes condition	across the moving mass/below/lateral						
			road and railways network	position with respect to the moving mass	across the moving mass/below/lateral	1	1	1	1	1	
				defence walls/grids	weak/resistant (material, type, shape); state of maintenance good/poor	1	1	1	1	1	
			tracks and ski runs	position with respect to the moving mass	across the moving mass/below/lateral	1	1	1	1	1	
		What are the factors that make production sites vulnerable	as for buildings								
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Preparedness	prior training and exercises; information about what do do	yes/no; frequency of training	1	1	1	1	1	
			Evacuation plan	binary and quality	yes/no; expert judgement	1	1	1 (only with meteo alert)	1 (only with meteo alert)	0	
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	yes/no; number of people	0	1	1	1	0	
	Community and Instituions	Factors that may lead to large number of victims	concentration	resident and present population in dangerous areas	presence with respect to the moving mass	1	1	1		1	

Matrix to assess physical vulnerability to landslides

Risk: Landslides **Third Matrix: Systemic vulnerability: Vulnerability to losses**

System	Component	Aspect	Parameters parameters	Criteria for assessment	Parameters values/categories	types of landslides: slow movement	types of landslides: rapid movement	Scoring
Natural environment	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	presence of forests/vegetation in denuded slopes	binary and extent	yes/no; types and % of coverage	1	1	
		Vulnerability of ecosystems to mitigation measures taken during emergency	presence of forests and ecosystems in the path where structural works have to be built	binary	yes/no; types and % of coverage	1	1	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Existance of public facilities: hospitals, fire brigades, emergency control rooms	yes/no; functional capacity of such facilities	assessment of functional potential of facilities	0	1	
			Range of service of public facilities	Importance of facilities in the potentially stricken areas	Local facilities/regional/national relevance	1	1	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Existance of lifelines	binary	yes/no	1	1	
			Degree of interdependance among lifelines	level of redundancy; binary	large redundancy; emergency devices exist/do not; autonomous capacity exist/does not	1	1	
			Continuity plan for lifelines, individually and in a coordinated fashion	binary	yes/no; considers all potential threats/does not	1	1	
			Degree of dependance of critical public facilities from lifelines	binary	autonomous plants exist/do not; alternative resources available/not available	1	1	
			People and areas depending on lifelines in potentially affected zones	number/area dimension	number of customers who may be affected; geographic area	1	1	
			Availability of personnel and spare materials for quick repairs	binary	yes/no	1	1	
			Duration of outages	hours	few hours/> 24	1	1	
		Accesibility to and within vulnerable areas	accessibility from/to damaged areas	to strategic facilities	more than 1 access/1 access/0 access	1	1	
				physical vulnerability of access ways	vulnerable/not vulnerable	1	1	
				condition and features of access ways	narrow/large (> or < 12 mt); inclination (> or < 3%), twisting and curves (yes/no), material (asphalt/not asphalt)	1	1	
			internal accessibility	in residential areas	more than 1 access/1 access/0 access	1	1	
				physical vulnerability of access ways	vulnerable/not vulnerable	1	1	
				condition and features of access ways	narrow/large (> or < 12 mt); inclination (> or < 3%), twisting and curves (yes/no), material (asphalt/not asphalt)	1	1	
			availbility of personnel and means for quick reopening	binary; distance in hours to be covered by personnel and means	yes/no; x < = 2h/ x> 2h	1	1	
	Production sites	Factors that make production sites vulnerable	Degree of dependance of production sites from lifelines	binary; degree of presence of autonomous devices	yes/no; %	1	1	
			Accessibility to the plant and to markets	see internal and particulary external accessibility of the area		1	1	
			Contingency plan for na-tech	binary	yes/no; considers all potential threats/does not	1	1	
			Business continuity plan	binary	yes/no	1	1	
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	information on risk	degree	enough/sufficient/none	1	1	
			trust in authorities	binary	yes/no	1	1	
	Community and Instituions	Factors that may hamper effective crisis management	continuouing monitoring	binary	yes/no	1	1	
			available equipments	binary	yes/no	1	1	
			potable water storage	binary	yes/no	1	1	
			civil protection plan	binary	yes/no	1	1	
			training and exercise	degree	frequent/not frequent; involving the population /not involving	0.5	1	
			communication plan (multilingual)	binary	yes/no	1	1	

Matrix to assess systemic vulnerability to landslides

Risk: Landslides **Fourth Matrix: Resilience: response capability in the long run**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Comments
Natural environment	*Natural ecosystems*	Ecosystems capacity to recover from damages	Type of forests damaged by landslide	depending on vegetation characteristics		
		Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	Type of forests damaged by landslide	depending on vegetation characteristics		
		Structural defences	Consolidation and drainage works	binary	feasible/not feasible; funding mechanisms in the reconstruction program	
			Defense grids	binary/funding	can be built/cannot be built; funding mechanisms in the reconstruction program	
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	New development and reconstruction programs include risk prevention as an everyday activity	degree	yes/partially/no	
			Detailed analysis of damage	degree and scale	yes/partially/no; at individual building/neighborhood/municipal scale	
			Lessons from landslides impact is considered for new construction and retrofitting	degree	yes/partially/no	
			Availability of partial relocation programs during reconstruction for the most critical situations	binary	yes/no	
			Relevance of potentially affected settlements in geographic/economic terms	degree of relevance	Central/peripheral	
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	
			In site devices for quick survey of damaged parts	binary	yes/no	
			Availability of personnel and spare materials for repairs	binary; time needed to bring on site spare materials	yes/no; < a day/>1 day	
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	degree; number of different stakeholders to be coordinated in repair efforts	yes/partially/no; protocols among all companies or coordinated by authorities/limited agreements	
			Lessons from landslides impact is considered for lifelines repair	degree	yes/partially/no	
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	binary	applicable/not applicable	
			Existance of funds for fast repairs	binary	yes/no	
			Existance of inspection and guiding personnel for correct repairs	binary	yes/no/forecasted in the recovery plans	
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of private resources to resettle/repair	binary and level of support by public organisations	yes/no; higly supported/lack of advisory personnel	
			Access to insurance	binary; percentage of coverage	yes/no; %without insurance	
	Community	Affected community's resilience to the consequences of a catastrophe	Employment rate	degree	high/medium/low	
			Annual population growth rate (over the last five years)	trend	high/medium/low/negative	
			Immigration index	new immigrants/emigrants	high/medium/low/negative	
			Social networking	qualitatie judgement	high/medium/low/negative	
			Criminality rate	degree	high/medium/low	
			Conflict among social/ethnic groups	degree	high/medium/low	
			Condition of affected part of the community with respect to the wider provincial context	degree	strongly connected/integrated/marginalized	
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	degree	high/medium/low (from sociological surveys when available)	
			Transparency in funds allocation	binary	Existance (yes/no) of public information and independent control mechanisms	
			Capacity to pursue mitigation strategies	Degree	yes/onlypartially/no	
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage for direct damage and loss of workdays	binary; percentage of coverage	yes/no; %without insurance	
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricoltural activity	percentage	

Matrix to assess resilience to landslides

Risk: volcanic **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Comments
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Volcanic hazard maps availability	binary; scale of detail	yes/no; local/regional	
		Available knowledge updating	Hazard maps updating	Frequency of updating	any time new knowledge is available/ any time activity changes/ only occasionally	
		Hazards monitoring	are volcanic hazards adequately monitored?	binary; quality and density of monitoring devices	yes/no; expert judgement	
		Integration of detection and monitoring systems with forecasting models	existence and quality of volcanic hazards monitoring systems	binary; expert judgement upon the quality of models; back analysis	yes/no; match of monitored data to forecasting models	
			are there early warning systems?	binary	yes/no	
		Structural defence measures			yes/no; quality of defences; state of maintenance	
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	binary; updating frequency	yes/no; any time new buildings are built/only occasionally	
			Risk maps and scenarios, including enchained events	binary	yes/no	
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yers/no; only formally/substantially with limitations and specific requirements	
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	binary; expert judgement	yes/no; taking into account new knowwledge and info/only occasionally updated	
			Traditional building practice based on hazard knowledge	?		
			Land use plans embedding risk mitigation and vulnerability reduction	binary; expert judgement	yes/no; sectoral/comprehensive; specific/generic	
			building codes/rules	binary; frequency of inspections; availability of trained personnel for inspections	yes/no; frequent/rare; yes/no and number/total of construction sites every year	
			Integration to other measures (insurance)	binary	yes/no	
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary ; updating frequency	yes/no; each time new projects are drawn/only occasionally	
			Maintenance programs embedding mitigation	binary ; updating frequency	yes/no	
			New projects based on hazard/risk assessment	binary	yes/no	
			Level of coordination among stakeholders	degree	low/medium/high	
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	binary ; updating frequency	yes/no; each time new plants or transformation of existing ones occurs	
			Retrofitting measures for existing production sites	binary	yes/no	
			New projects based on risk assessment	binary	yes/no; special provisions for hazardous plants/generic rules	
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary; expert judgement on quality	yes/no; good/poor quality	
Social system (agents)	*People/individuals*	Evaluation of the capacity of individuals living in prone hazard areas of coping with hazardous events	Risk perception/ awareness	degree	inexistant/average/good	
			Early warning systems	information addressing all components of communiy(ies)	% of coverage	
			Individual preparedness	availability of masks and sholves	yes/no	
			Known evacuation procedures	binary; training	yes/no; training every few years/ only occasionally	
	Community and Instituions	Involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	degree	low/average/high	
			Education programs & media campaigns	binary; frequency	yes/no; every two years/only occasionally	
				embedded in school programs	yes/no; every two years/only occasionally	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	low/average/high	
	Economic stakeholders	Level of preparedness of key economic stakeholders	GDP; GVA (Gross added value, measure of productivity and size of economy)	level	rich/average/poor country	
			extent of marginalized groups	dimension of poverty/marginalization	percentage of people living with less than x/year	

Matrix to assess mitigation capacity to volcanic risk

Risk: Volcanic **Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters value/categories	Relevance with respect to volcanic hazards: gas	tephra	pyroclastic flows	ballistic	lava flows	lahars	Score
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	presence of vegetation and forests on the volcanic slopes	binary; coverage and type	yes/no; % and type			1	0.5	1	1	
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard	type of soil; vegetation	rock/varioustypes of loose soil; trees with long and extended roots/no vegetation or with superficial roots	qualitative	0	0.5			1	-	
		Vulnerability of ecosystems to mitigation measures taken during emergency	presence of ecosystems that may be endangered by lava flows deviations	binary; type	yes/no; type of vegetation and other species	0			0	1		
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Vulnerability assessment of public facilities	internal machinery sensitive to the volcanic hazards	yes/no; type of machinery		0.5	1		1	1	
			Average vulnerability at the municipal scale, considering settlements or urban partitions	Considering parameters provided in the attached specific table	Low-medium-high vulnerability	1	1	1	1	1	1	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines)	electricity and communication	lines	aerial lines/underground			1			1	
				power station, telecom centre	see buildings assessment		1	1	1		1	
			gas	position of gas conducts	across hazardous zones		1	1			1	
				connection to buildings	vulnerable buildings/not vulnerable)							
			water and sewerage	position of water pipes	across hazardous zones		1 (across landslide)				1	
				pipes condition	obsolete/new							
			position	distance from dangerous areas	inside/outside potentially affected areas (scenario dependent)		1	1			1	
			point shaped elements	bridges	weak/resistant (material, type,		1(debris	1	1		1	
		Factors that make production sites vulnerable	presence of flammable materials	binary; amount	yes/no; quantities							
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Preparedness	prior training and exercises; information about what do do	yes/no; frequency of training	1	1	need to be evacuated	need to be evacuated		need to be evacuated	
			Sensitivity to health effects of volcanic hazards	means of self protection	yes/no;	1	1	-	-	-	-	
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	yes/no; number of people	0.5	0.5	1	1	1	1	
	Community and Instituions	Factors that may lead to large number of victims	concentration	resident and present population in dangerous areas	inside/outside potentially affected areas (scenario dependent)	1	1	1	1		1	

Matrix to assess physical vulnerability to volcanic risk

Aspect	Aspect Parameters	Criteria for assessment	Parameter value /categories	gas	tephra	pyroclastic flows	ballistic	lava flows	lahars
Factors that make buildings and public facilities vulnerable to the stress	Vulnerability assessment of residential buildings and public facilities	roof	connection to structure	good/poor		1		1	
			weight	heavy/light		1			
			shape	large inclination/plane		1 (pitch > 15° ok)		0.5	
		structure	material	iron, reinforced concrete, masonry (different types), other		0,5 (worse: timber)	0,5 (best: r.c, masonry if homog. resistance; worse: timber)		
			homogeneity	large/largely disomogenous		1	1	1	
			type of connection among parts	good/poor		0.5	0.5	0.5	0.5
			floors rigidity	rigid/non rigid					
		foundation	depth and type	non-existent, deep, superficial			1		1
		spans between resistant elements	distance in m.	> 3 mt; < 3 mt (for masonry mainly)		0.5			
		shape	openings	number and dimension of windows/doors	1	1	1		0.5
			quality of openings	may be easily sealed/not	1	1	1		
			basement	existant/non existant	1				
			inflammable objects	existant/non existant	1	0.7	0.7	0.5	0.5
			sources of radiation or toxic chemicals	existant/non existant					
		maintenance	building conditions	very poor/ good		1	1	1	1
		position	soil on which the building is built (crest, alluvial deposits, etc.)	amplification soils yes/no	0.5				
			with respect to dangerous channels	parallel/perpendicular			1		1
			distance from dangerous areas	inside/outside potentially affected areas (scenario dependent)	0.5	0.5	1	1	1

Matrix to assess physical vulnerability of built environment to volcanic risk

Risk: volcanic **Third Matrix: Systemic vulnerability: Vulnerability to losses**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Scoring
Natural environmer	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	induced lahars; induced landslides	binary; extent	yes/no; maps	
		Possibility of enchained effects due to the interaction of natural systems with the triggering hazard		meteorological assessment in the days after the initial crisis	rainy/dry	
		Vulnerability of ecosystems to mitigation measures taken during emergency	presence of forests and ecosystems in the path where lava flows are going to be deviated	binary	yes/no; types and % of coverage	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Quality of temporary shelters (first emergency)	with heating or conditioning; sanitation; density	yes/no; a>1/50 people/ a < 1/50 people; d < 1tent per family/d > 20 persons/tent	
			Quality of more permenent temporary shelters	dimension; availability of services	d > 14 mq/4 persons/ d < 10 mq/4 persons; yes/no	
			Accessibility to potentially damaged areas from temporary shelters	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
			Accessibility to work sites from temporary shelters	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
			Accessibility to public facilities	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	gas, water, electricity, telecom	existence and redundancy	more than 1/ 1/ 0	
				fucntional vulnerability to physical damage (physical vulnerability)	vulnerable components crucial for functioning: yes/no	
				dependency from other systems	dependent/autonomous	
			accessibility from damaged areas	to strategic facilities	more than 1 access/1 access/0 access	
				physical vulnerability of access ways	vulnerable/not vulnerable	
				condition and features of access ways	narrow/large (> or < 12 mt); inclination (> or < 3%), twisting and curves (yes/no), material (asphalt/not asphalt)	
			internal accessibility	in residential areas	more than 1 access/1 access/0 access	
				physical vulnerability of access ways	vulnerable/not vulnerable	
				condition and features of access ways	narrow/large (> or < 12 mt); inclination (> or < 3%), twisting and curves (yes/no), material (asphalt/not asphalt)	
			external accessibility	heliports	existent/non existent	
					accessibility from settlements (as accessiblity to strategic facilities)	
					physical vulnerability (as roads position parameter)	
					gathering zones close	
				ports	existent/non existent	
					accessibility from settlements (as accessiblity to strategic facilities)	
					physical vulnerability (as roads position parameter)	
					gathering zones cloes	
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	binary; degree of presence of autonomous devices	yes/no; %	
			Accessibility to the plant and to markets	see internal and particulary external accessibility of the area		
			Contingency plan for na-tech	binary	yes/no; considers all potential threats/does not	
			Business continuity plan	binary	yes/no	
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	self protection means	yes/no	1 (masques)	1 (shovels)
			information on risk	enough/sufficient/none	1	1
			trust in authorities	yes/no	1	1
	Community and Institutions	Factors that may hamper effective crisis management	permanent staff	yes/no	1	1
			continuouing monitoring (>weight if early warning possible)	yes/no	1	0.5
			available equipments	yes/no	1 (masques)	1 (drill)
			potable water storage	yes/no	1	1
			civil protection plan	yes/no	1	1
			training and exercise	frequent/not frequent; involving the population /not involving	1	1
			communication plan (multilingual)	yes/no	1	1

Matrix to assess systemic vulnerability to volcanic risk

Risk: volcanic **Fourth Matrix: Resilience: response capability in the long run**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Scoring
Natural env	*Natural ecosystems*	Ecosystems capacity to recover from damages	can it be as ofr fires?			
		Ecosystems capacity to recover from secondary negative effects of emergency mitigation measures	can it be as ofr fires?			
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Temporary transferability of facilities relevant for the settlement/city community life and economy	binary; type of relocation	yes/no; temporary/permanent	
			Existance of plans for reconstruction in case of severe destruction scenarios	binary	yes/no	
			Level of sharing among stakeholders of reconstruction plans	degree	High/low; only formal/substantial	
			Level of integration of physical reconstruction with community healing processes	degree	High/low; room for interpreting in the new/restored setting the meaning of the destruction	
			Relevance of potentially affected settlements in geographic/economic terms	level of importance	Central/peripheral	
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	
			In site devices for quick survey of damaged parts	binary	yes/no	
			Availability of spare materials for fast repairs	binary; time needed to bring on site spare materials	yes/no; t < 1 day/ several days	
			Availability of personnel for repairs	location and number of technicians	on site/in distant areas; number of available technicians with respect to expected need	
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	degree; number of different stakeholders to be coordinated in repair efforts	yes/partial/no; one main stakeholder/several stakeholders	
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	binary	applicable/not applicable	
			Existance of funds for fast repairs	binary	yes/no	
			Existance of inspection and guiding personnel for correct repairs	binary	yes/no/forecasted in the recovery plans	
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	binary	yes/no	
			Availability of private resources to resettle/repair	binary; support by public agencies; rapidity of compensation process	yes/no; available/not available; rapid/slow	
			Access to insurance	binary and coverage	yes/no; percentage of coverage	
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Areas vitality	Aging population; low fertility rates	
			Local condition of aged population	binary	autonomous/not autonomous; relatively healthy/not healthy	
			Employment rate	degree	high/medium/low	
			Annual population growth rate (over the last five years)	degree	high/medium/low/negative	
			Immigration index	degree	high/medium/low/negative	
			Social networking	degree	high/medium/low/negative	
			Criminality rate	degree	high/medium/low	
			Conflict among social/ethnic groups	degree	high/medium/low	
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	degree	high/medium/low (from sociological surveys when available)	
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no	
			Long term vision	Existance of strategic development/land use plans	yes/no	
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	binary and coverage	Yes/no;percentage	
			Construction industry	level of development and modernization	high/average/low	

Matrix to assess resilience to volcanic risk

Risk: seismic **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Application or comments from case studies
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard mapsincluding map for fault rupturing at the ground surface availability	At the following scales: country level; regional and provincial; lower scales	yes/no; quality as judged with respect to international standards and updated to new knowledge and technologies	In the Alaska case (earthquake 1964) geological hazards connected to seismic were well known and mapped, though not embedded in metropolitan master plans of Anchorage for example
			Geological map of quaternary formation			
			Map of topographic amplification zones			
		Hazard monitoring	availability of seismographs and accelerometers networks	binary and density	yes/no; dense/only individual sparse points	In Italy before the 70s the seismograph and accelerometers networks were significantly underdeveloped/absent in several zones
		Induced/triggered hazards consideration in hazard monitoring systems	Availability of maps of landslides and estimation of their potential movement consequent to earthquakes	binary; quality	yes at appropriate scale/no; quality with resepct to international standards	Induced and triggered hazards have been the object of study only recently; many regions though have developed such knowledge in the last ten/15 years
			Map of potential liquefaction zones	binary; coverage	yes/no; only spot like/covering the entire area of concern	
			Map of tsunami hazard	binary	yes/no	
			Tsunami monitoring network	binary	yes/no	
Built environment	*Exposure and vulnerability of built environment*	Is exposure and vulnerability considered and acted upon in plans?	Vulnerability assessment of exposed built stock	binary; frequency	yes/no; updated at the same rate of urban growth/not updated	In Italy for example extensive vulnerability survey campaings have been carried out in several regions
			Risk maps and scenarios, including enchained events	binary	yes/no	
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations in amplification zones and specific building requirements	Unfortunately available vulnerability assessment, including the assessment of all public buildings vulnerability in Southern regions is not considered in development/restoration plans in the majority of Italian regions
	Rules and tools for risk mitigation	Inclusion of vulnerability and exposure assessments in land use plans	Building codes/rules	binary; quality	yes/no; updated according to state of the art/old	Various cases, like the Kocaeli earthquake have shown the importance of cosndiering the year when building codes were issued
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	binary; judgement about the capacity to conform to the "code of practice"	Expertise has been developed in Italy for example regarding the issue of "code of practice" connecting traditional local knowledge and earthquake resistance capacity; provisions for retrofitting have been attached to the financial law after earthquakes
			Maintenance of built stock	binary	yes/no	
			Specific provisons for retrofitting	binary	economic incentives promoted/not promoted	
			Land use plans embedding risk mitigation and vulnerability reduction	binary/ expert quality judgement	yes/no; sectoral/comprehensive; specific/generic	
			Implementation capacity	binary; frequency of inspections; availability of trained personnel for inspections	yes/no; frequent/rare; yes/no and number/total of construction sites every year	In several recent earthquakes (Gujarat, 2001; Turkaey, 1999; Algeria, 2003; L'Aquila 2009 poor compliance was one of the main casuses of recent buildings failure
			Integration to other measures (insurance)	binary	yes/no	Only in Turkey after the 1999 earthquake the program funded by the World Bank connects insurance to antiseismic development
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary ; updating frequency	yes/no; each time new projects are drawn/only occasionally	Relevant in California
			Maintenance programs embedding mitigation	binary ; updating frequency	yes/no	In California there is a tradition that permitted the seismic upgrading of lifelines in ordinary maintenance and new projects
			New projects based on hazard/risk assessment	binary	yes/no	
			Level of coordination among stakeholders	degree	low/medium/high	
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites	binary ; updating frequency	yes/no; each time new plants or transformation of existing ones occurs	
			Retrofitting measures for existing production sites	binary	yes/no	
			New projects based on risk assessment	binary	yes/no; special provisions for hazardous plants/generic rules	
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary; expert judgement on quality	yes/no; good/poor quality	
			Existance of emergency plans that expliclty take into account erthquakes as threat to be prepared for	binary; expert judgement on quality	yes/no; good/poor quality	
Social system (agents)	*People/individuals*	Capacity of individuals living in prone hazard areas of coping with hazardous events, which largely depends on the perception and awareness of risk conditions	Risk perception/ awareness	degree	inexistant/average/good	
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	low/average/high	Even in Kobe the individual preparedness proved to be poor despite national programs; few people had radio working with batteries; few had a bottle of water and basic commodities ready for evacuation
	Community and Instituions	Evaluation of the involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees through information and education campaigns and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Participation in development and prevention/mitigation strategies	degree	low/average/high	
			Education programs & media campaigns	binary; frequency	yes/no; every two years/only occasionally	
				embedded in school programs	yes/no; every two years/only occasionally	
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	low/average/high	
	Economic stakeholders	Economic capacity to mitigate of the various stakeholders; the access to financial resources for mitigation	GDP, GVA (Gross added value, measure of productivity and size of economy)	level	rich/average/poor country	
			extent of marginalized groups	dimension of poverty/marginalization	percentage of people living with less than x/year	

Matrix to assess mitigation capacity to seismic risk

Risk: seismic

Second Matrix: Physical vulnerability: Vulnerability to stress (hazard)

	System	Aspect	Parameters	Criteria for assessment	Descriptors	Application or comments from case studies
Natural e	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	extent of potentially flooded zones by tsunami	degree and relevance of impacted zones	extended areas/few zones; urban areas impacted/remote areas	
			extent and location of triggered landslides	degree and relevance of impacted zones	extended areas/few zones; urban areas impacted/remote areas	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Average vulnerability at the municipal scale, considering settlements(rural) or urban parts	Considering parameters provided in the attached specific table	Low-medium-high vulnerability	
			Vulnerability assessment of historic buildings/monuments	Specific vulnerability indicators depending on the type of building/structure	Low-medium-high vulnerability	
			Vulnerability assessment of public facilities	as for residential buildings		
				internal machinery vulnerable to shakes	yes/no; adapted to seismic shaking/not adapted	
			Vulnerability of the urban fabric	vulnerability assessment of structural built aggregates	on the basis of: regularity; presence of strong inclination; presence of structural disomogenity	The urban fabric is not the simple addition of buildings, particularly in historic centres where a set of buildings sharing structural components like walls manifest a rather different behavior to shaking than if the buildings were not connected. This behavior has been surveyed in several earthquakes in Italy and elsewhere
				relationship between built and open areas	large spaces between buidlings and open spaces availble/dense and narrow built zones	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulenrable (mainly lifelines	Vulnerability assessment of lifelines	electricity (including nodes like power stations	derived from e.g. network caracteristics (buried/aerial	Earthquake lifelines engineering is a branch of civil and seismic engineering devoted to the understanding of lifelines behavior under shaking and induced stresses (liquefaction, landslides, etc.). First extensive reports go back to the Northridge earthquake in 1994, the Kobe earthquake in 1995 and all following earthquake. Studies are polarized between very technical issues regarding the behavior of individual components, like bridges, valves, joints, pipes on the one hand and the systemic functioning of lifelines on the other.
				communication (including nodes like base transceiver station,...)	derived from e.g. network caracteristics (buried/aerial,!), conditions (age, degree of maintenance), network redundancy	
				gas network (including nodes like production facilities, tank farms, stations,...)	derived from e.g. network caracteristics (rigid/ductile material, existence of shut-off valves/circuit-breakers!), conditions (age, degree of maintenance), network redundancy	
				water, drinking water and sewerage network (including dams, treatment plants, pumping stations, ...)	derived from e.g. network caracteristics (rigid/ductile material, existence of shut-off valves/circuit-breakers!), conditions (age, degree of maintenance), network redundancy	
				transport lines: roads, railways for instance (including bridges, tunnels, embankment/slopes!)	derived from e.g. network caracteristics (type of material, !), conditions (age, degree of maintenance), network redundancy	
			Presence of dams	binary; assessed vulnerability to earthquakes	yes/no; low/medium/high	
			Vulnerability due to physical interaction among lifelines	lifelines degree of connection	low/high	
			Vulnerability due to lifeline connections physical interaction with to vulnerable buildings	lifelines close and attached to resistant/vulnerable buildings	yes/no	
	Production sites	Factors that make production sites vulnerable (including na-tech potential)	Vulnerability assessment of production sites	as for public facilities		Na-tech have been only recently the object of systematic studies; in the seismic field in particular after the Kocaeli earthquake in 1999 where an important refinery exploded and burned as a secondary consequence of the earthquake
			Potential na-tech due to stored materials, types of processes	binary and number of workers, types of processes	yes/no; small/large firms , processes types	
			Vulnerability due to dependency on lifelines	dependance on lifelines	low/medium/high (existence of alternative solutions)	
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	People concentration in different zones in the hours of the day	degree of concentration in vulnerble locations/buildings	low/medium/high	The Kobe eartheuake is an example of vulnerable residential buildings where many people died; the Alaska earthquake just the opposite, as many more people would have died were the people working in the central district heavily affected by landlsides
			Preparedness	previous training	yes/no	
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	yes/no, number of people	
	Community and Instituions	Factors that may lead to large number of victims	Existance of emergency plan and quality	binary; quality	yes/no; as judged by involved institutions	In several cases the lack of basic SAR tools has casued the increase of victims trapped under debris. Studies show that in the first 24 hours the same victims are the first reponders
			Availability of resources for search and rescue (lamps; cranes, special devices)	binary; number with respect to potentially damaged areas	yes/no; imemdiately accessible/remote; sufficient/not sufficient	

Matrix to assess physical vulnerability to seismic risk

Vulnerability parameters for individual buildings

Aspect	Parameters	Criteria for assessment	Descriptors (in order of higher vulnerability)	weight	score (1=high; 5=very low)	Comments
What are the factors that make buildings and public facilities vulnerable to the stress?	Vulnerability assessment of residential buildings and public facilities	roof connection to the building structure	good/mediocre/poor			Those parameters are quite well established in the international literature, unlike for other hazards. The process of identifying correlations between damage acceleration-vulnerability is quite developed in several countries, with large damage database that permit to identify the main causes of failures of ordinary structures. Special facilities likfe hospitals, theaters, churches hav been less studied and only recent reports permit to establish the vulenrability of special buildings and stored machinery/goods. After the Northridge earthquake some articles report the vulnerability of hospitals and special equipments incuding generators
		roof weight	light/heavy			
		structural material	iron, r.c. antiseismic, timber/masonry/stone,un cooked earth			
		connection among walls and building parts	good/mediocre/poor			
		floors rigidity	flexible/rigid			
		foundation depth and type	deep/superficial/non existent			
		position with respect to soil type	non amplification zones/amplification areas/liquefaction zones			
		spans between resistant elements (mainly masonry)	d < 3 m/d > 3 m			
		openings	part of the structure/create structural discontinuity			
		regularity in plan	regular/asymmetric distribution of forces			
		regularity in elevation	regular/asymmetric distribution of forces			
		added parts (balconies, chimneys)	attached/loosely connected to structure			
		maintenance	good/poor			
		retrofitting programs	available/not available; good/poor			

Matrix to assess physical vulnerability of built environment to seismic risk

Risk: seismic **Third Matrix: Systemic vulnerability: Vulnerability to losses**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	categories	Comments from case studies
Natural environment	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	areas affected by landslides	number and extent	few/many; in remote areas/in crucial-central zones	
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Availability of rapid post seismic buildings usability assessment	forms pre-prepared and shared among all teams	yes/no	The l'Aquila case showed that the existenc of various forms reduces the efficiency of usability srveys, as well as the lack of comuterized systems for their fast recovery and particularly georeferencing.
				information computerized	yes/no	
				rapid damage assessment map obtained in few weeks	yes/no	
			Quality of temporary shelters (first emergency)	with heating or conditioning; sanitation; density	yes/no; a>1/50 people/ a < 1/50 people; d < 1tent per family/d > 20 persons/tent	The availability of human conditions in temporary camps is essential for peple's recovery, particularly when the earthquake strikes in winter
			Quality of more permenent temporary shelters	dimension; availability of services	d > 14 mq/4 persons/ d < 10 mq/4 persons; yes/no	As temporary shelters in seismic hit zones are expected to last some years, they must be provided with a minimal level of commodities. In the meantime accessibility to working places and homes is essential for victims
			Accessibility to potentially damaged areas from temporary shelters	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
			Accessibility to work sites from temporary shelters	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
			Accessibility to public facilities	on foot; transportation	d < 500 m/ d> 500 m; available/not available; frequent/not frequent	
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Redundancy in lifelines systems	degree	low/high	The capacity to isolate priority nodes for fast recovery of lifelines; the availability of tanks, generators and any other means to make lifelines and critical facilities work at least partially after the event is clearly crucial also for carrying out emergency operations. The Kobe and the Northridge earthquakes showed clearly that such availability is much less available than thought and than what would be required and possibile thanks to modern technologies
			Degree of interdependance among lifelines	degree	low/medium/high	
			Availability of emergency devices	binary (generators; tanks, etc)	yes/no	
			Continuity plan for lifelines, individually and in a coordinated fashion	binary and quality	yes/no; considers also induced hazards/ does not	
			Degree of dependance of critical public facilities from lifelines	degree	low/medium/high	
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	degree	low/medium/high	
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time	redundant/not redundant; open/close roads; t.inc < 30 min/ t.inc > 30 min	
			Contingency plan for na-tech	binary	yes/no; considers all potential threats/does not	
			Business continuity plan	binary	yes/no	
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	Access to understandable information	binary	yes/no; centralized /at each group level (for example in each temporary camp)	
			Trust in information provisers	degree	low/medium/high	
			Preparedness to evacuation	individual plan	yes/no (like going to relatives)	
			Presence of impaired groups (elderly, sick persons, etc.)	binary and quality of caring	yes/no; capacity to provide treatment in temporary camps/or not	In the l'Aquila case an accurate survey of people needing care for cronic deseases whas conducted and patients were given thier treatment since the first days
	Community and Institutions	Factors that may hamper effective crisis management	Existance of contingency plan fro threats at stake	binary; date of last production or update	yes/no; recent/old	
			availability of quick post event scenarios to be checked and used as a guidance in crisis management	binary and quality	yes/no; considering also enchained effects and systemic damage/restricted to physical damage	Comfort (1999) refers to the Northridge earthquake when repsonders could count on available pre-set scenarios for rapid damage estimation
			Training using the contingency plan	binary; frequency of training	yes/no; every two years/only occasionally	
			Overlapping responsiblities among agencies	degree	Low/medium/high	Overlapping responsibilities between the firemen and other technicians of the civil protection in usability surveys and first shoring have sometimes delayed surveys and return of people to undamaged houses in the l'Aquila case
			Established protocols for information sharing	binary	yes/no	
			Established protocols for use of resources to manage the crisis	degree	yes/only partially/high	

Matrix to assess systemic vulnerability to seismic risk

Risk: seismic **Fourth Matrix: Resilience: response capability in the long run**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Comments from case studies
Built environment	*Exposure and vulnerability of built environment*	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Temporary transferability of facilities relevant for the settlement/city community life and economy	binary; type of relocation	yes/no; temporary/permanent	In the l'Aquila case all public services located in the historic centre were transferred to the School of the Financial Police in an external quartier nearby. The problem of leaving a centre empty of functions for a long while must be carefully considered
			Existance of plans for reconstruction in case of severe destruction scenarios	binary	yes/no	
			Reconstruction plans considers lessons learnt from earthquake (including amplification zones)	binary and quality	yes/no; seismic zonation map made available for reconstruction/not available	In the Umbria Marche case (1997) provision of compensation was granted on the basis of a seismic zonation map showing the most critical amplification zones
			Existance of skilled workers/firms for repairs and reconstruction (example historic sites)	binary; quality	Yes/no; availability with respect to expected need	In the Umbria Marche case, the lack of firms with workers skilled in the restoration of historic centres and in the meantime seismic retrofitting required careful consideration and creation of technical consultancy by the two regions
			Level of sharing among stakeholders of reconstruction plans	degree	High/low; only formal/substantial	The Umbria Marche case showed a good level of integration between the central government and the two regions.
			Level of integration of physical reconstruction with community healing processes	degree	High/low; room for interpreting in the new/restored setting the meaning of the destruction	
			Relevance of potentially affected settlements in geographic/economic terms	level of importance	Central/peripheral	
Infrastructure and production sites	*Critical infrastructures*	Availability of tools to recover critical infrastructures rapidly and at low costs	Computerized mapping systems of infrstructures	binary	yes/no	The Kobe earthquake has shown that recovery time is strongly connected to the availability of personnel, maps of systems, material for repairs, capacity to handle car traffic in areas where repairs must be carried out
			In site devices for quick survey of damaged parts	binary	yes/no	
			Availability of spare materials for fast repairs	binary; time needed to bring on site spare materials	yes/no; t < 1 day/ several days	
			Availability of personnel for repairs	location and number of technicians	on site/in distant areas; number of available technicians with respect to expected need	
			Existance of protocols to proceed with repairs requiring inter-lifelines interventions	degree; number of different stakeholders to be coordinated in repair efforts	yes/partial/no; one main stakeholder/several stakeholders	
	Production sites	Availability of tools to recover production sites rapidly and at low costs	Temporary transferability of production in case of need	binary	applicable/not applicable	
			Existance of funds for fast repairs	binary	yes/no	
			Existance of inspection and guiding personnel for correct repairs	binary	yes/no/forecasted in the recovery plans	
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	
Social system (agents)	*People/individuals*	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	binary	yes/no	In the l'Aquila case provision of psychological support for victims was extensive and helped to solve several problems in temporary tent camps
			Availability of private resources to resettle/repair	binary; support by public agencies; rapidity of compensation process	yes/no; available/not available; rapid/slow	
			Access to insurance	binary and coverage	yes/no; percentage of coverage	
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Areas vitality	Aging population; low fertility rates	After the Friuli earthquake in 1976, several centres were rebuilt in areas that had experienced high levels of abandonment: several empty buildings can be found nowadays in the rebuilt zone.
			Local condition of aged population	binary	autonomous/not autonomous; relatively healthy/not healthy	
			Employment rate	degree	high/medium/low	
			Annual population growth rate (over the last five years)	degree	high/medium/low/negative	
			Immigration index	degree	high/medium/low/negative	
			Social networking	degree	high/medium/low/negative	
			Criminality rate	degree	high/medium/low	
			Conflict among social/ethnic groups	degree	high/medium/low	
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Degree of trust in institutions	degree	high/medium/low (from sociological surveys when available)	
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no	The Friuli earthquake in 1976 was a good example of transparency a sort of collective control over money expenditure was developed; on the contrary the Irpinia reconstruction after the 1980 earthquake was object to several court and parlamentary trials for briberies etc.
			Long term vision	Existance of strategic development/land use plans	yes/no	
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	binary and coverage	Yes/no;percentage	
			Construction industry	level of development and modernization	high/average/low	

Matrix to assess resilience to seismic risk

Risk: forest fire **First Matrix: Resilience: Mitigation capacity**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	weight	score (1=high; 5=very low)	Scale
Natural environment	*Natural Hazards*	Natural hazards identification and mapping	Hazard maps availability	Maps of areas prone to fires; map of inflammability of vegetation	yes/no; quality as judged with respect to international standards	1		
			Do hazard assessment consider climate change	binary	yes/no	0.5		
		Available knowledge updating	Hazard maps updating	Frequency of updating	every 2 years and after each event/rarely	0.5		
		Hazard monitoring systems	Existence, distribution and quality of monitoring networks	technical monitoring systems linked to operation centre	yes/no	1		
				permanent staff dispaced in critical areas for direct monitoring and immediate intervention	yes/no	0.5		
		Connection of monitoring devices to modelling systems	Availability, quality of early detection systems and models	binary; quality of early detection and propagation estimation models	yes/no; models tailored to the geographical context/not tailored	0.5		
		Structural defence measures	Existence of defenses for breaking the fire lines	binary	yes/no	1		
Built environment	*Exposure and vulnerability of built environment*	Inclusion of vulnerability and exposure assessments in land use plans	Vulnerability assessment of exposed built stock	binary; updating frequency	yes/no; every time new building permits are given/only occasionally	1		
			Risk maps and scenarios, including enchained events	binary; year of production	yes/no	1		
			Vulnerability and exposure assessment considered in ordinary plans (example land use)	binary; mode of inclusion	yes/no; only formally/substantially with limitations and specific requirements	1		
	Rules and tools for risk mitigation	Availability, quality and efficacy of mitigation rules	Building codes/rules	binary; updated	yes/no; rules efficacy checked after each event/rarely tested	0.5		
			Property regime of houses	owned houses versus tenants	owners ow < 50%/ ow > 80%	0.5		
			Traditional building practice based on hazard knowledge	binary; capacity to re-produce traditional techniques correctly	yes/no; judgement about the capacity to conform to the "code of practice"	0.5		
			Maintenance of fire suppression devices and clearing vegetation around houses	binary	yes/no	1		
			Land use plans embedding risk mitigation and vulnerability reduction	binary; specific indications for vulenrable locations	yes/no; specific rules for the wildland-urban interface and for accessibility	1		
			If previous paramters yes, then Implementation capacity	binary; frequency of inspections; trained personnel for inspections	yes/no; every year/seldom	1		
			If previous paramters yes, then Integration to other measures (insurance)	binary	yes/no	1		
Infrastructure and production sites	*Critical infrastructures*	Existence of vulnerability assessments for critical facilities; level of consideration of vulnerability in programs regarding critical facilities	Vulnerability assessment of critical infrastructure	binary, particularly for roads and water for firefighting	yes/no	1		
			Maintenance programs embedding mitigation	binary	yes/no	1		
			New projects based on hazard/risk assessment	binary	yes/no	1		
			Level of coordination among stakeholders	degree	low/medium/high	1		
	Production sites	Existence of vulnerability assessments for production sites; consideration of na-techs	Vulnerability assessment of production sites to wildfire	binary	yes/no	1		
			Retrofitting measures for existing production sites	binary	yes/no	1		
			New projects based on risk assessment	binary	yes/no	1		
			Na-tech explicitly accounted for in hazardous installations emergency plans	binary	yes/no; expert judgement on quality	1		
Social system (agents)	*People/individuals*	Capacity of individuals living in prone hazard areas of coping with hazardous events, which largely depends on the perception and awareness of risk conditions before the event occurs.	Risk perception/ awareness	Degree	strong/average/low	0.5		
			Reliance on institutional firefighting capabilities	Degree	strong/average/low	1		
			Felt responsibility for firefighting and fire mitigation	Degree	strong/average/low	1		
			Tools and plans to guarantee early warning reach the communities	Binary	yes/no	1		
			Individual preparedness	regarding specific self protective measures; regarding measures included in emergency plans	hydrant available/not available; escaping routes known/not considered	1		
	Community and Institutions	Evaluation of the involvement of a community into decision-making processes related to risk prevention and mitigation, the capacity of Instituions of improving risk awarenees through information and education campaigns and the level of cooperation among different institutions in charge of risk prevention/ mitigation.	Contingency plans for firefighting	binary	yes/no	1		
			Effectiveness of measures included in contingency plans	degree	strong/medium/low	1		
			Participation in development and prevention/mitigation strategies	degree	strong/medium/low	0.5		
			Education programs & media campaigns	binary; frequency	yes/no; every year/only seldom	0.5		
				tailored to the community features	yes/generic	1		
				Inclusion in school programs	yes/no	1		
			Economic access to resources for firefighting	degree	vewry low/low/average/high	1		
			Coordination and cooperation among institutions in charge of risk prevention/ mitigation	degree	strong/medium/low	1		

Matrix to assess mitigation capacity to forest fires

Risk: forest fires; **Second Matrix: Physical vulnerability: Vulnerability to stress (hazard**

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	weight	score (1=high; 5=very low)	Scale
Natural environment	*Natural ecosystems*	Fragility of natural ecosystems to hazard(s)	land cover inflammability	Surface fuels	Only needle or leaf litter on the ground; sparse low vegetation; tall dense phyrgana or shrubs	1		
				Existence and cover of tall tree crowns	No tree crowns; tree crown cover of <40%; tree crown cover >= 40%	0.5		
				Type of trees (see next page for details)	according to the classification provided by Dimitrakopoulos and Papaioannou, 2001	1		
		Vulnerability of ecosystems to mitigation measures taken during emergency	can natural ecosystems may be impacted by mitgiation measures?	Binary	Yes/no	0.5		
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to the stress	Average vulnerability at the municipal scale, considering settlements(rural) or urban parts	Considering parameters provided in the attached specific table	Low-medium-high vulnerability	1		
			Types of dangerous uses within or in proximity to the building unit of reference (either in the horizontal or vertical sense)	Flammable storage inside or close to residential areas	Absent/present	0.5		
			Morphological features of settlements	Influence of the slope of the surrounding area	Slope i <5%/ 5% <= i < 20 / Slope >= 20%	0.5		
			Historic sites (archeological) and buildings (monuments and museums) in the hazardous areas	Binary; extent and relevance	no/yes; dimension; minor/relevant/very relevant	1		
			If previous parameter YES, then Level of protection	Binary and quality	yes/no; effective/uneffective	1		
			Built pattern (follwoing Lampin-Maiillet et al., 2009)	Building density and proximity is an indicator for assessing potential sources of ignition and surface to be cleared from vegetation	very dense; dense, scattered; isolated	1		
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures vulnerable (mainly lifelines)	Vulnerability assessment of critical infrastructure	water system pressure	normal/ too low pressure for hydrants	1		
				self eater tank	available/not available	1		
			roads	interaction with fuel	large road sections in open zones/in the middle of fuel areas	1		
	Production sites	Factors that make production sites vulnerable (including na-tech potential	Vulnerability assessment of production sites	as for buildings, but including attention to storage of hazmat	structurally vulnerable/low vulenrability; large storage/no storage	1		
			Vulnerability due to dependency on lifelines	depending on the degree of dependance upon external vulnerable lifelines	self eater tank available/not available	1		
Social system (agents)	*People/individuals*	Factors that may lead to injuries and fatalities	Sparse population	ratio between population living in isolated buildings and remote settlements and total population	r <5%; r > 20%	1		
			Preparedness	self protection means	hydrants at home/lack of hydrants	1		
				self protection against smoke	availability of masks/lack of	1		
			Age; mobility impairment, other impairment	difficulties to comply with evacuation orders; difficulties in escaping	> 65; number of handicapped	1		
	Community and Instituions	Factors that may lead to large number of victims	Distance from firefighting resources	time of arrival	within 30 min; > 1 hour	1		
			Availability of trained personnel	professional training in the community	firefighters (professional+volunteers)/only professional	1		

Matrix to assess physical vulnerability to forest fires

Vulnerability parameters for individual buildings

Aspect	Parameters	Criteria for assessment	Parameters value/ categories	weight	score (1=high; 5=very low)	Application to the Ilia case study
What are the factors that make buildings and public facilities vulnerable to the stress?	Vulnerability assessment of residential buildings and public facilities	Minimum distance between the forest fuel and the house	Distance d >= 20 m; d< 20m			Post-fire case studies revealed that ~90% of home survival depended on two factors: a non-flammable roof and vegetation cleared within 10 m of home (Foote, 2006)
		Heat tolerance of the roof	Non flammable roof/flammable roof			
		Influence of the slope of the surrounding area	Slope i <5%; 5% <= i < 20; i >= 20%			
		Heat tolerance of the walls	Non burnable walls/ flammable walls			
		Heat tolerance of the shutters	Metal shutters/wood or plastic shutters			
		Number of floors	Only ground floor/2 floors/ > 2floors			

Matrix to assess physical vulnerability of built environment to forest fires

Risk: forest fire;

Third Matrix: Systemic vulnerability: Vulnerability to losses

	System	Aspect	Parameters	Criteria for assessment	Descriptors	weight	Score 1 (high) - 5 (low)	Comments
Natural er	*Natural ecosystems*	Fragility of ecosystems to potential secondary effects of hazard(s)	soil deterioration	increase of erosion	<= 30 %; 30 x x < 50%; x>= 50%	1		
			landslide hazard	degree of increase of landslide potential based on survey and exprt judgement	low/medium/high	1		
Built environment	*Exposure and vulnerability of built environment*	Factors that make buildings, the urban fabric and public facilities vulnerable to losses	Existence of public facilities and resources to face the emergency	Availability of movable fire fighting equipment or of an automatic fire-fighting network (E3)	yes/no	1		
			Accessibility to vulnerable areas	Buildings density and proximity (follwoing Lampin-Maiillet et al., 2009)- total perimeter to be protected	very dense; dense, scattered; isolated	1		
				Roads characteristics	Type of roads serving the various settlements Plain roads/mountain roads			
				Signs in roads and streets (names, numbers, etc.)	yes/no			
				existence of public facilities in the area	yes/no			
			Accessibility to public facilities	expected travel time	t > 30 min/ t <= 30 min			
				road network to public facilities	as for accessibility to vulnerale areas			
Infrastructure and production sites	*Critical infrastructures*	Factors that make critical infrastructures stop functioning	Existance of lifelines	Availability of water for firefighting	Yes/no; in sufficient number/insufficient	1		
					Existence of a swimming pool or a water tank of more than 3 m3 in the plot	0.5		
	Production sites	Factors that may lead to halting production	Degree of dependance of production sites from lifelines	water for fighting	existence of tanks and devices for firefighting			
			Accessibility to the plant and to markets	redundancy; quality of roads; usability; expected increase in travel time	as for roads network to vulnerable areas			
			Contingency plan for na-tech	binary	yes/no			
			Business continuity plan	binary	yes/no			
Social system (agents)	*People/individuals*	Factors that may reduce coping capacity during crisis	Access to understandable information	binary	yes/no	1		
			Trust in information provisers	binary	yes/no	1		
			Tenants, landowners and neighbours have been trained in fire-fighting	binary and frequency of training	yes/no; every x months/only occasionally	1		
			Voluntary fire fighers	binary; number	yes/no; number /neighborhood	1		
			If previous yes, then Training	degree of training and means availability to volunteers	good/average/low	1		
			Presence of impaired groups (elderly, sick persons, etc.)	binary; number and accessibility to leaving areas	yes/no; numbr/neighborhood and accessibility	1		
	Community and Instituions	Factors that may hamper effective crisis management	Existance of contingency plan fro threats at stake	binary; date of last production or update	yes/no; recent/>2 years with no updating	1		
			If previous yes, Training using the contingency plan	binary; frequency of training	yes/no; every year/only occasionally	1		
			Overlapping responsiblities among agencies	degree	Low/medium/high	0.5		
			Established protocols for information sharing	binary	yes/no	0.5		
			Established protocols for use of resources to manage the crisis	degree	yes/no/partial	0.5		

Matrix to assess systemic vulnerability to forest fires

Risk: forest fires

Fourth Matrix: Resilience: response capability in the long run

System	Component	Aspect	Aspect Parameters	Criteria for assessment	Parameters values and/or categories	Weight	Score 1 (high) - 5 (low)	Comments
Natural environment	Natural ecosystems	Ecosystems capacity to recover from damages	recovery capacity of burnt areas	extent of damage to vegetation	Resprouting likely/unlikely	1		
			Fire interval	Elapsed time between two consecutive fires (The study by Delgado etal 2002 is used as reference. They evaluated resilieance of vegetation in the Mediterranean context, using Catalonia as a case study. The type of vegetation studied should be similar for many mediterranean ecossystems. They measure plant cover recovery 38 months after the second fire).	Days	1		
			Fire recovery	Post fire vegetation re-growth	South facing slopes/North facing slopes	0.5		
				logging procedures	immediate logging after fire/delayed logging (see Spanos et al., 2010)	0.5		
			burnt areas management	plants used for reforestation	use of endemic species for reforestation/use of fast growing vegetation	1		
		Structural and non structural recovery measures	availability of maps and pictures to document regeneration	binary	yes/no	0.5		
Built environment	Exposure and vulnerability of built environment	Urban fabric/built environment capacity to recover reducing pre-event vulnerability	Existance of plans and provisions to encourage mitigation in buildings and surrounding zones	binary	yes/no	1		
			Creation of emergency access	binary	yes/no	1		
			Level of sharing among stakeholders of reconstruction plans	degree	low/average/high	1		
			Level of integration of physical reconstruction with community healing processes	Room is given for interpreting in the new/restored setting the meaning of the destruction (After Valen and Campanella, 2005)	High/low	0.5		
			Existence and strength of norms prohibiting building in burnt areas	binary; degree of compliance/inspection capability	yes/no; low/high			
Infrastructure and production sites	Critical infrastructures	Availability of tools to recover critical infrastructures rapidly and at low costs	Water system for firefighting	level of improvement after disaster	low/high	1		
			In site devices for quick survey of damaged parts	binary	yes/no	1		
			Availability of spare materials for fast repairs	binary	yes/no	1		
			Availability of personnel for repairs	binary	yes/no	1		
			Existence of protocols to proceed with repairs requiring inter-lifelines interventions	binary	yes/no	0.5		
	Economic activities	Availability of tools to recover production sites rapidly and at low costs	Relevance of the area as a tourist attraction	degree	low/average/high	1		
			Activities depending on the existence of woods	binary	yes/no	0.5		
			Economic sectors	Diversified or concentrated on few sectors	Few/many different economic sectors in the area	1		
Social system (agents)	People/individuals	People's resilience in the face of the catastrophe induced trauma	Availability of psychological support for adults and children	degree	yes/no/making part of ordinary practices			
			Availability of private resources for recovery	degree	yes/no			
			Availability of private resources for recovery	Income/per capita	high/average/low			
			Access to insurance	binary; coverage	yes/no; percentage of coverage			
	Community	Affected community's resilience to the consequences of a catastrophe	Age structure	Aging population; low fertility rates	indexes			
			Local condition of aged population	autonomous/not autonomous; relatively healthy/not healthy	autonomous/not autonomous; relatively healthy/not healthy			
			Employment rate	degree	high/medium/low			
			Annual population growth rate (over the last five years)	degree	high/medium/low/negative			
			Immigration index	degree	high/medium/low/negative			
			Social networking	degree	high/medium/low/negative			
			Criminality rate	degree	high/medium/low			
			Conflict among social/ethnic groups	degree	high/medium/low			
	Institutions	Transparency, reliability and trustability of institutions in charge of reconstruction	Trust in institution	degree	high/medium/low (from sociological surveys when available)			
			Transparency in funds allocation	Existance of public information and independent control mechanisms	yes/no			
			Long term vision	Existance of strategic development/land use plans	yes/no			
	Economic stakeholders	Capacity and willingness of stakeholders to reinvest in affected areas	Insurance coverage	binary; coverage	Yes/no;percentage			
			Dependance of economic actors on loss of environmental goods	Prevalent tourist acitvity; agricultural activity	percentage			

Matrix to assess resilience to forest fires

7 Appendix B: Workshop

WORKSHOP

Creating tools for vulnerability assessment

17th June 2010: 10.00 – 18.00

Politecnico di Milano, Aula Master, 5th floor, via Bonardi 3, Milan

10.00 – Presentation of the current state of the Ensure project
Scira Menoni

11.30 - Presentation of invited guests work on vulnerability, continuation
Nicholas Kyriakopoulos, University of Washington: framing and measuring systemic vulnerabilities

12.45 - Time for first impressions and short discussion

13.00 - Lunch

14.30 – Ali Asgary, University of York: Practicing with vulnerabilities: identifying weaknesses and opportunities for coping in a simulation exercise.
Participants: Ensure project partners and invited speakers

15.30 - Coffee break

16.00 - Discussion on basic aspects of vulnerability assessment: existing tools and gaps to be addressed by future research.

17.15 - Summing up: an external perspective on the Ensure project by invited speakers:
Philip Buckle
Nicholas Kyriakopoulos
Jeroen Warner